

TRACE METAL CONCENTRATIONS IN THE OFFSHORE WATERS
AND SEDIMENTS OF LAKE SUPERIOR

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Under Contract With:
United States Environmental Protection Agency
Grant Numbers R005730-1, R005510-03

Project Officer:
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536 S. Clark Street
Chicago, Illinois 60605

Special Report No. 121
Great Lakes Research Division
The University of Michigan
Ann Arbor, Michigan

1986

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ACKNOWLEDGMENTS

I thank Timothy Henry and James Barres for analysis of the samples and the captain, crew, and scientists aboard the CSS Limnos for assistance with sample collection. A special thanks to Environment Canada for the opportunity to collect samples from the CSS Limnos.

INTRODUCTION

For all of the Great Lakes combined, a relatively large data base for trace metals in water exists. Relative to Lakes Huron, Erie, and Michigan, the Lake Superior data base is small. To date, no one has attempted to synthesize the available data and critically examine their usefulness for describing long-term water quality trends with respect to the metals.

As was the case for Lakes Huron (Rossmann 1982), Erie, and Michigan (Rossmann 1984a), the Lake Superior historical trace metal data base is a mixture of total and dissolved metal concentrations. Unlike those of Lakes Huron, Michigan, and Erie, the Lake Superior data base is dominated by dissolved metal concentrations. The historical data base is derived from the STORET data base, data compiled by the Upper Lakes Reference Group (IJC 1977) from STORET and unpublished Michigan Department of Natural Resources data, Weiler and Chawla (1969), Weiler (1978), Chau and Saitoh (1973), and Poldoski et al. (1978).

The historical data base derived from the above sources spans the years 1968 to 1976. To these years are added the data from the current study conducted in 1983. This study was carried out by the Great Lakes Research Division of The University of Michigan and supported by the Great Lakes National Program Office of the United States Environmental Protection Agency. The purpose of this report is to provide additional baseline trace metal data for Lake Superior and to comment on the quality of the existing historical data base.

METHODS

COLLECTION

During September 1983, 20 stations were occupied to collect trace metal water samples (Fig. 1). All collections were made from the CSS Limnos.

Routinely, samples were collected from a water depth of 1 m using a trace metal-free polyethylene sampling system. The system used was capable of being rinsed with lake water at the sampling depth prior to collection of the sample. Details of the sampling procedure and sampler used are described in Rossmann (1982, 1984a). Sampling was replicated at two of the twenty stations. Samples from depths greater than 1 m were collected with Niskin bottles using a Rossette sampler. No special precautions were taken to prevent metal contamination of the Niskin bottles. The bottles were being used routinely for collection of monitoring samples and were unavailable for special cleaning. A total of 35 samples was collected.

All samples to be filtered were passed through Millipore Fluoropore filters (FEP teflon) having a pore size of 0.5 μm . One-liter filtered and total metal samples were stored in precleaned polyethylene bottles containing 5 mL of concentrated Ultrex nitric acid. Filtered and total mercury samples were stored in one-liter precleaned glass bottles containing 10 mL of concentrated sulfuric acid and 10 mL of 5% potassium dichromate. All samples were analyzed for dissolved and particulate concentrations of iron, zinc, arsenic, cadmium, chromium, copper, lead, nickel, selenium, aluminum, barium, boron, manganese, silver, vanadium, cobalt, molybdenum, strontium, lithium, beryllium, tin, antimony, mercury, and bismuth. Filters containing particulate matter were stored in precleaned polyethylene vials in a freezer until extraction with Ultrex nitric

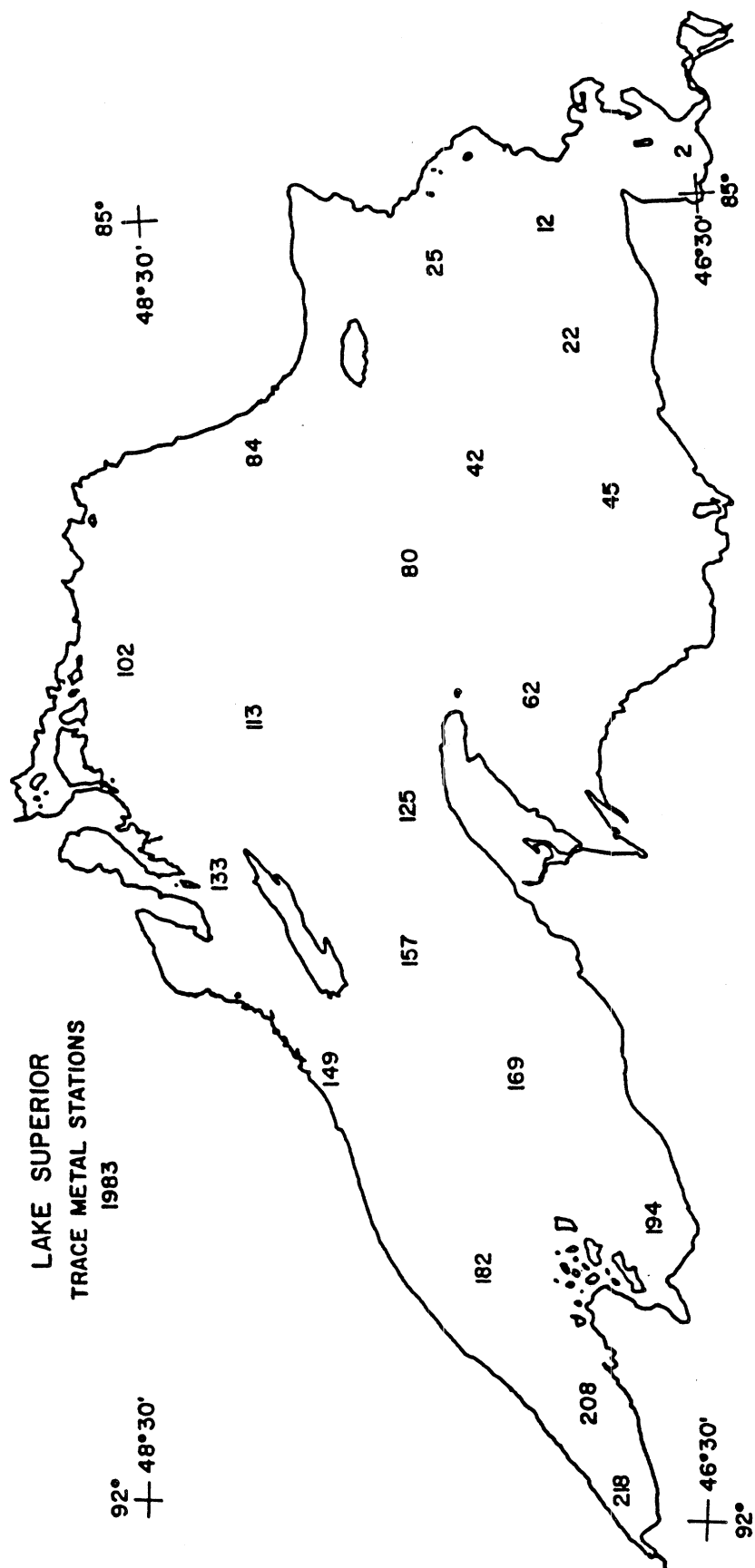


Figure 1. Trace metal water sampling stations in Lake Superior for 1983.

acid and hydrogen peroxide. Details of the extraction procedure are discussed by Rossmann (1982).

ANALYSES

All metal analyses, excluding mercury and strontium, were done by flameless atomic absorption spectrophotometry using a graphite furnace (Perkin-Elmer 1977, Rossmann 1982). For most metals, 100 μ L of sample were injected to obtain the low detection limits necessary for those samples. All quantitation was with a standard curve. In general, past work showed the method of standard additions to be unnecessary or unfeasible for the low concentrations to be measured (Rossmann 1982). Strontium was analyzed by the method of standard additions using flame atomic absorption spectrophotometry. Mercury analyses were done using the gold-amalgam technique (Perkin-Elmer 1981). Quantitation was with a standard curve. Interferences precluded the use of a standard curve for numerous metals. Metals analyzed by the method of standard additions were dissolved boron and tin and particulate selenium, beryllium, boron, strontium, arsenic, and bismuth. Samples required freeze-drying prior to analysis for silver, boron, beryllium, bismuth, nickel, arsenic, antimony, selenium, tin, vanadium, and cobalt. All concentrations were calculated in the same manner as described by Rossmann (1982).

Limit of Detection

For each run consisting of standards, blanks, and samples, the limit of detection (minimum instrument response level) was determined by calculating the standard deviation of readings for multiple atomizations of air or distilled-deionized water. The standard deviations obtained from each of these blanks

were then averaged, multiplied by 1.96 to provide for the 95% level of confidence (Hoel 1967), and divided by the slope of the regression line for the standards to convert to a concentration. Metals with a concentration below the limit of detection (W) are identified in the Appendices. At the 95% level of confidence, the average limits of detection for all runs of each element are listed in Table 1.

Criterion of Detection

For all water analyses, a criterion of detection, minimum concentration that can be detected as being significantly different from a blank, was calculated for each metal. The criterion of detection was obtained by calculating the standard deviation of the appropriate blank concentration and then multiplying by 1.96 to provide for the 95% level of confidence (Hoel 1967). The criterion of detection for each metal is listed in Table 2. Metals having concentrations below the criterion of detection (T) are identified in the Appendices.

Blanks

For each metal analyzed, sample blanks were analyzed. The total metal blank consisted of a bottle containing the appropriate preservative, to which one liter of distilled-deionized water was added. The filtered metal blank consisted of a bottle containing the appropriate preservative, into which one liter of distilled-deionized water was filtered. This served not only to provide a blank but also further to clean the filter prior to filtration of the lake water sample. Total and filtered metal blanks were collected at every station. Because both the sampler bottle and storage bottles were polyethylene and cleaned in the same manner, the blanks represented not only handling and storage contamination but also sampler contamination. If any median blank concentration was appreciably large relative to measured sample concentrations, sub-samples

Table 1. Mean limits of detection for analysis of 1983 Lake Superior water samples.

Metal	Mean Limit of Detection, ppb ¹	
	Dissolved or Total	Particulate
Ag ²	0.0016(0.00085)	0.00030(0.00024)
Al	0.11(0.10)	0.015(0.0077)
As ²	0.029(0.019)	0.050(0.048)
B ²	11.(5.8)	4.6(3.2)
Ba	0.80(0.51)	0.060(0.038)
Be ²	0.0015(0.0010)	0.0015(0.00082)
Bi ²	0.013(0.0031)	0.017(0.0082)
Cd	0.0020(0.00081)	0.0039(0.00090)
Co ²	0.010(0.0020)	0.0013(0.000055)
Cr	0.015(0.0074)	0.00095(0.00090)
Cu	0.033(0.027)	0.0028(0.0016)
Fe	0.087(0.065)	0.028(0.0065)
Hg	0.0069(0.0057)	---
Li	0.026(0.019)	0.0060(0.0049)
Mn	0.011(0.0046)	0.029(0.016)
Mo	0.044(0.042)	0.0040(0.0038)
Ni ²	0.014(0.013)	0.0075(0.0029)
Pb	0.027(0.0019)	0.0020(0.00070)
Sb ²	0.032(0.012)	0.0047(0.0026)
Se ²	0.032(0.012)	0.042(0.021)
Sn ²	0.015(0.015)	0.085 ³
Sr	0.057(0.015)	0.028(0.022)
V ²	0.018(0.011)	0.0050(0.0026)
Zn	0.078(0.037)	0.0085(0.0047)

¹Mean followed by standard deviation in parentheses.

²Concentrated 10-fold by freeze-drying.

³All samples run at the same time; hence, only one limit of detection.

Table 2. Criteria of detection for analysis of 1983 Lake Superior water samples.

Metal	Particulate Metal Criterion of Detection, ppb	Dissolved or Total Metal Criterion of Detection, ppb
Ag	0.00029	0.0043
Al	0.033	0.65
As	0.040	0.14
B	3.6	51.
Ba	0.10	1.4
Be	0.0099	0.020
Bi	0.020	0.11
Cd	0.0085	0.0076
Co	0.0024	0.012
Cr	0.0080	0.043
Cu	0.014	0.11
Fe	0.043	0.35
Hg, dissolved	---	0.037
Hg, total	---	0.042
Li	0.0075	0.024
Mn	0.00095	0.010
Mo	0.0095	0.035
Ni	0.0040	0.029
Pb	0.0025	0.055
Sb	0.011	0.025
Se	0.072	0.061
Sn	0.050	0.015
Sr	0.051	5.5
V	0.0085	0.013
Zn	0.011	0.14

of the distilled-deionized water utilized to prepare the blanks were analyzed. After correction for the distilled-deionized water blanks, the total and dissolved blanks were used to correct sample results. The blank corrections used are listed in Table 3. Blanks for dissolved lead, cadmium, mercury, and zinc, particulate cadmium, and total mercury were relatively high compared to sample concentration. This was probably due to shared use of the ship and the lack of clean rooms aboard the ship and in with the analytical facility.

Inter-laboratory Comparison

In addition to our normal quality control procedures (Rossmann 1982), samples provided by the Data Quality Work Group of the International Joint Commission (Inter-laboratory Study No. 46, Trace Metals in Water) were analyzed at the same time as the Lake Superior water samples. Metals which were analyzed early enough for inclusion in the inter-laboratory comparison included cadmium, cobalt, chromium, iron, manganese, lead, and nickel. Our laboratory's results and the median concentrations calculated for all participating laboratories are presented in Table 4. Samples with metal concentrations exceeding our normal working range were reported as "greater thans" (>). With the exception of nickel and aluminum, all results were satisfactory. For these, a low bias was given; however, no individual analysis was flagged as being low. In no instances were our results flagged as being high, representing possible sample contamination.

Table 3. Blank corrections applied to 1983 Lake Superior trace metal results.

Metal	Correction for Particulate Samples (ppb)	Correction for Unfiltered Samples (ppb)	Correction for Filtered Samples (ppb)
Ag	0.0	---	0.0021
Al	0.32	---	0.75
As	0.0	---	0.0
B	2.4	---	32.
Ba	0.090	---	0.0
Be	0.0032	---	0.0
Bi	0.0	---	0.0
Cd	0.022	---	0.010
Co	0.0030	---	0.0
Cr	0.0085	---	0.020
Cu	0.037	---	0.066
Fe	0.090	---	0.28
Hg	---	0.054	0.054
Li	0.0	---	0.0
Mn	0.0022	---	0.012
Mo	0.0	---	0.0
Ni	0.018	---	0.022
Pb	0.0038	---	0.078
Sb	0.0075	---	0.0
Se	0.0	---	0.0
Sn	0.0	---	0.0
Sr	0.096	---	0.0
V	0.011	---	0.018
Zn	0.033	---	0.12

Table 4. Performance of the Great Lakes Research Division (GLRD) trace metal laboratory in Interlaboratory Comparability Study No. 46 administered by the Data Quality Work Group of the International Joint Commission (concentrations in ppb).¹

Metal	1		2		3		4		5		6		7		8		9		10	
	GLRD	Median	GLRD	Median	GLRD	Median	GLRD	Median	GLRD	Median	GLRD	Median	GLRD	Median	GLRD	Median	GLRD	Median	GLRD	Median
Al ²	5.8	6.6	5.9	7.0	7.0	12.	9.5	16.	20.	100.	20.	200.	390.	20.	53.2	20.	540.	20.	960.	
Cd	0.026	0.15	0.029	0.10	0.12	0.15	>0.15	0.50	>0.15	1.1	>0.15	3.0	>0.15	5.0	>0.15	2.1	>0.15	10.	>0.15	43.
Co	0.21W	0.50	0.21W	0.50	0.24	0.37	0.39	1.2	0.92	1.2	4.9	4.9	9.5	9.0	>10.	14.	>10.	21.	>10.	54.
Cr	0.38	0.50	0.31	0.70	>1.0	1.0	—	2.0	—	4.7	—	25.	—	48.	—	11.	—	80.	—	100.
Cu	>1.5	4.0	>1.5	4.6	1.5	2.8	>1.5	3.4	>1.5	7.1	>1.5	15.	>1.5	11.	>1.5	21.	>1.5	48.	>1.5	110.
Fe	4.1	8.2	4.1	6.0	>5.0	13.	>5.0	13.	>5.0	42.	>5.0	160.	>5.0	190.	>5.0	130.	—	320.	—	540.
Mn	0.24	0.34	0.25	0.50	>0.40	1.3	>0.40	2.8	>0.40	5.7	>0.40	50.	—	25.	—	11.	—	77.	—	210.
Mo	0.20	1.0	0.16	0.20	1.4	1.2	—	2.0	—	5.0	—	26.	—	50.	—	10.	—	110.	—	218.
Ni	0.14	1.0	0.056	0.95	0.33	1.0	0.38	1.0	1.5	2.0	4.8	6.0	3.6	4.2	2.1	2.7	>7.5	19.	>7.5	56.
Pb	0.52	1.0	0.49	1.0	1.3	2.0	1.7	3.0	>2.0	10.	>2.0	52.	>2.0	98.	>2.0	40.	>2.0	160.	>2.0	212.
V ²	0.62	0.26	0.33	0.30	1.4	1.0	1.5	1.9	1.3	1.1	5.0	5.9	>10.	19.	>10.	48.	>10.	80.	>10.	110.

¹Samples 1 and 2 were taken from the same bulk, unfiltered Lake Superior water sample.

²Run after submission of other results to IJC; hence, not included in IJC report.

Coefficient of Variation (Relative Deviation)

Samples were collected in replicate at two stations to provide an estimate of the coefficient of variation of the sampling and analysis (Table 5). Metals for which the particulate concentration was a substantial fraction of the total metal concentration tended to have high coefficients. Those metals included aluminum, cadmium, iron, and lead. Their high coefficients of variation were most likely due to the attempt to sample a heterogeneous lake. High coefficients for other metals result from contamination problems and the measurement of concentrations near the limit or criterion of detection.

Samples were analyzed in triplicate for a number of metals. For those metals for which analyses were replicated, an analytical coefficient of variation was calculated (Table 6). Freeze-dried samples and particulate samples were usually not run in replicate because of the very small sample volumes available. In general, the coefficients of variation were small. Compared to other metals, coefficients of variation for total and dissolved mercury and particulate copper were high. This is due to the observed concentrations being near the limit of detection.

Analysis of USEPA Water Pollution Quality Control Sample

USEPA water pollution quality control sample 4 of set WP475 was analyzed as a quality control measure. Because concentrations of the diluted concentrate were much too high relative to lake water concentrations, 0.5 mL instead of 10 mL of concentrate were diluted into 1 L of water, providing concentrations 20 times lower than those intended by USEPA. For all metals whose concentrations fell within our normal working range, GLRD results compared favorably with the true value or the mean concentration provided by USEPA (Table 7). In all other instances, GLRD results fell within the 95% confidence interval. Because GLRD results were derived for samples 20 times more dilute than the USEPA results, this is considered good performance.

Table 5. Mean coefficient of variation for collection and analysis of 1983 Lake Superior water samples.¹

Metal	Coefficient of Variation (%)	
	Dissolved	Particulate
Ag	--	28
Al	124	20
As	10	--
B	--	9
Ba	4	--
Be	--	--
Bi	--	37
Cd	30	3
Co	--	--
Cr	16	12
Cu	10	22
Fe	46	6
Hg	--	--
Li	3	--
Mn	11	4
Mo	6	--
Ni	41	199
Pb	144	27
Sb	41	--
Se	46	28
Sn	--	--
Sr	9	--
V	24	49
Zn	62	0

¹Coefficient of variation calculated only for replicates having at least one sample above the criterion or limit of detection.

Table 6. Mean coefficient of variation for analysis of 1983 Lake Superior water samples.¹

Metal	Coefficient of Variation (%)		
	Dissolved	Particulate	Total
Ag	0	9	--
Al	5	8	--
As	12	--	--
B	--	--	--
Ba	1	--	--
Be	--	--	--
Bi	--	--	--
Cd	6	--	--
Co	9	--	--
Cr	4	--	--
Cu	2	20	--
Fe	3	8	--
Hg	42	--	24
Li	1	--	--
Mn	4	--	--
Mo	6	--	--
Ni	8	7	--
Pb	6	--	--
Sb	10	--	--
Se	9	--	--
Sn	--	--	--
Sr	6	--	--
V	14	--	--
Zn	11	7	--

¹Particulate and freeze-dried dissolved metals were usually not run in replicate because of sample volume limitations; hence, no coefficients of variation could be calculated.

Table 7. Results of analysis of USEPA water pollution quality control sample WP475-sample 4 (ppb).

Metal	True Value	USEPA			GLRD	
		Mean	Standard Deviation	95% Confidence Interval	Mean	Standard Deviation
Al	3.0	4.2	1.0	2.3-6.1	4.1	(0.064)
As	1.1	1.2	0.11	0.94-1.4	1.2	(0.014)
Cd	0.12	0.12	0.0087	0.10-0.14	0.11	0.00058
Cr	0.50	0.51	0.055	0.40-0.62	0.44	(0.032)
Co	1.0	1.0	0.12	0.78-1.2	1.0	(0.13)
Cu	0.55	0.56	.13	.30-.82	0.56	(.015)
Pb	1.2	1.2	0.18	0.86-1.6	1.2	0.039
Hg	0.075	0.076	0.022	0.032-0.12	0.11	0.020
Ni	1.5	1.5	0.30	0.88-2.1	1.5	0.021
Se	0.30	.28(0.07)		0.14-0.42	0.37	(0.0)
V	3.5	3.4(0.41)		2.5-4.2	3.6	(0.056)
Zn	0.80	0.85	0.18	0.48-1.2	1.1	0.21

RESULTS AND DISCUSSION

In the sections which follow, the 1983 lake water trace metal concentrations as well as summarized historical data are presented for each metal. The historical data were summarized by year. In several instances, data for the same year may have been available from more than one source. Thus, data which are similar for more than one entry of the same year may represent different reports of the same data. Other than the STORET data, the data could not be sorted for nearshore and offshore stations. Only offshore data were selected from the STORET data base. All historical data must be used with caution. At the time of their generation, they may or may not have represented high quality data for the state-of-the-art methodology used. The results for each metal measured in 1983 by GLRD as well as identified historical data are presented in the sections which follow. All 1983 results are summarized in the Appendices. Data are reported in the manner recommended by the International Joint Commission, including results below the limit or criterion of detection and including negative results (ASTM 1980). Because historical data represent samples taken at different times of the year, in different places, and analyzed or collected by different procedures, trends inferred from use of the historical data must be used with caution. The trends are presented to illustrate what can be done with the available data.

SILVER (Ag)

With a median dissolved silver concentration of -0.0032 ppb, all but one of 1983 Lake Superior water analyses were below the limit or criterion of detection (Table 8). No historical data were found.

The 1983 median particulate silver concentration was 0.0012 ppb (Table 9). No historical particulate or total silver data were found. The total metal median concentration, derived from summing dissolved and particulate results, was -0.0012 ppb (Table 10).

Table 8. Dissolved silver concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1983 ¹	22	-0.0047	0.0099	-0.0020	0.0030	-0.0032

¹This study.

Table 9. Particulate silver concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1983 ¹	22	0.00075	0.0032	0.0013	0.00051	0.0012

¹This study.

Table 10. Calculated total silver concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1983 ¹	22	-0.0033	0.011	-0.00068	0.0030	-0.0012

¹This study.

ALUMINUM (Al)

For 1983, the median dissolved aluminum concentration was 1.2 ppb (Table 11). No historical data were found.

The 1983 median particulate aluminum concentration was 2.6 ppb (Table 12). For 1977, the median particulate concentration was considerably higher than that of 1983. The 1983 median total aluminum concentration was considerably lower than that of 1977 (Table 13); however, there was no significant difference between the means of the 2 years. Differences are probably due to differences between areas sampled for the 2 years.

Table 11. Dissolved aluminum concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1983 ¹	22	-0.035	10.	1.8	2.5	1.2

¹This study.

Table 12. Particulate aluminum concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1977 ¹	7	4.4	36.	16.	14.	8.9
1983 ²	22	0.20	23.	4.1	4.8	2.6

¹Eisenreich (1982).

²This study.

Table 13. Total aluminum concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1977 ¹	7	<2.0	13.	7.5	3.7	9.2
1983 ²	22	1.1	24.	6.0	5.4	3.8

¹Eisenreich (1982).

²Calculated from this study.

ARSENIC (As)

Historical dissolved arsenic data for Lake Superior waters were found for the period of 1973-4 (Table 14). The median for 1983 open waters was 0.52 ppb. Nearly all the particulate concentrations were below the criterion or limit of detection. Summary statistics are in Table 15. The calculated total metal median concentration was 0.46 ppb (Table 16).

Table 14. Dissolved arsenic concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1973-4 ¹	12	0.6	1.2	0.78	0.19	--
1983 ²	22	0.40	0.90	0.55	0.13	0.52

¹Calculated from means for various coastal and embayment sites given in IJC (1977).

²This study.

Table 15. Particulate arsenic concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1983 ¹	22	-0.037	0.050	0.011	0.025	0.010

¹This study.

Table 16. Total arsenic concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1973-4 ¹	12	0.7	0.9	0.82	0.072	---
1975 ²	5			0.8	0.1	
1983 ³	22	0.43	0.90	0.56	0.13	0.52

¹Calculated from means for various coastal and embayment sites given in IJC (1977).

²Nearshore waters (Poldoski et al. 1978).

³Calculated from this study.

BORON (B)

The only historical epilimnion boron data found were for one analysis in 1974 (Table 17). All of the 1983 dissolved boron concentrations were below the criterion of detection or the limit of detection. Nearly 73% of all particulate analyses were below the limit of detection or criterion of detection (Table 18).

Table 17. Dissolved boron concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1974 ¹	1			50.		
1983 ²	22	-42.	25.	-22.	14.	-27.

¹STORET.

²This study.

Table 18. Particulate boron concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1983 ¹	22	-4.2	24.	1.3	5.8	-0.90

¹This study.

BARIUM (Ba)

No historical barium data for lake water were found. The median dissolved, particulate, and calculated total concentrations for 1983 were 21, 0.025, and 21 ppb, respectively (Tables 19-21).

Table 19. Dissolved barium concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1983 ¹	22	17.	27.	21.	2.4	21.

¹This study.

Table 20. Particulate barium concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1983 ¹	22	-0.057	0.29	0.068	0.092	0.025

¹This study.

Table 21. Calculated total barium concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1983 ¹	22	17.	27.	21.	2.4	21.

¹This study.

BERYLLIUM (Be)

No historical beryllium data for Lake Superior water could be found. For 1983, all dissolved and particulate beryllium concentrations were below the 0.0015 ppb limit of detection (Tables 22-23).

Table 22. Dissolved beryllium concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1983 ¹	22	-0.047	-0.013	-0.029	0.012	-0.032

¹This study.

Table 23. Particulate beryllium concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1983 ¹	22	-0.0052	-0.00018	-0.0026	0.0014	-0.0026

¹This study.

BISMUTH (Bi)

No historical data on bismuth for Lake Superior water could be found. For 1983, all dissolved bismuth concentrations were below the 0.013 ppb limit of detection (Table 24). The majority of the 1983 particulate bismuth concentrations were below the 0.020 ppb criterion of detection (Table 25). The median particulate concentration in 1983 was 0.0050 ppb.

Table 24. Dissolved bismuth concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1983 ¹	22	-0.16	-0.023	-0.10	0.055	-0.13

¹This study.

Table 25. Particulate bismuth concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1983 ¹	22	-0.026	0.034	0.0031	0.015	0.0050

¹This study.

CADMIUM (Cd)

Historical data for dissolved cadmium were found for four years (Table 26). The 1983 mean and median concentrations are considerably lower than those for the historical data. Detection limits for the historical data appear to have been above 0.1 ppb. This and apparent contamination problems make the historical data useless for interpreting long-term changes in cadmium concentrations.

Table 26. Dissolved cadmium concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1970 ¹	--	--	--	<1.	--	--
1970 ²	--	--	--	<0.2	--	--
1971 ¹				0.4	0.3	--
1971 ²	--	--	--	<0.20-0.40	--	--
1971 ³	37	0.10	3.0	0.51	0.48	0.50
1973 ¹	694			0.1	0.2	0.0
1973 ²	--	---	---	<0.20-0.30	---	---
1973-4 ⁴	9	<0.03	0.17	0.071	0.051	---
1983 ⁵	22	0.0010	0.012	0.0066	0.0030	0.0060

¹Weiler (1978).

²IJC (1977), Michigan Department of Natural Resources and STORET data.

³STORET.

⁴Calculated from means for various coastal and embayment sites given in IJC (1977).

⁵This study.

Historical data for particulate cadmium were found for one year (Table 27). The particulate concentrations of 1977 and 1983 had very similar ranges; however, the 1977 median concentration was considerably lower than that of 1983. This is due to either increased cadmium concentrations or a more representative coverage of the lake for 1983.

Table 27. Particulate cadmium concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1977 ¹	7	0.002	0.04	0.01	0.01	0.004
1983 ²	22	0.001	0.038	0.021	0.010	0.021

¹Eisenreich (1982).

²This study.

Historical data for total cadmium were found for one year (Table 28). The minimum concentration observed for 1977 was lower and the maximum for 1977 was higher than those of 1983. The 1983 median of 0.027 ppb was considerably lower than that for 1977. The 1977 may be high biased due to a less extensive region of the lake being sampled.

Table 28. Total cadmium concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1977 ¹	7	<0.02	0.25	0.12	0.10	0.13
1983 ²	22	0.070	0.044	0.027	0.010	0.027

¹Eisenreich (1982).

²Calculated from this study.

COBALT (Co)

Historical data for dissolved cobalt in Lake Superior waters are available for three years (Table 29). Minimum historical concentrations are at least three times the maximum concentration measured for 1983. A combination of sample contamination and relatively high limits of detection most likely account for this and make the historical data useless for assessing long-term trends. The majority of the 1983 data were below the 0.010 limit of detection.

Table 29. Dissolved cobalt concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1970 ¹	--	--	--	0.55	--	--
1970 ²	--	--	--	1.	1.	--
1970 ³	5	1.0	1.0	1.0	0.0	1.0
1971 ¹	--	--	--	<0.50	--	--
1971 ²	--	--	--	0.5	0.4	--
1971 ³	30	0.10	2.0	0.66	0.50	0.50
1973 ¹	--	--	--	<0.50	--	--
1973 ²	700	--	--	0.2	0.3	0.1
1983 ⁴	22	-0.00036	0.032	0.0096	0.0087	0.0058

¹IJC (1977), Michigan Department of Natural Resources and STORET data.

²Weiler (1978).

³STORET.

⁴This study.

No historical data for particulate cobalt were found. The majority of the 1983 particulate data were below the 0.0024 criterion of detection (Table 30). The median total cobalt concentration was 0.0082 ppb which was much less than that for 1970 (Table 31). The 1970 data were at the limit of detection and are not useful for assessing trends.

Table 30. Particulate cobalt concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1983 ¹	22	-0.0030	0.0092	0.00038	0.0024	-0.000050

¹This study.

Table 31. Total cobalt concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1970 ¹	4	1.0	1.0	1.0	0.0	1.0
1983 ²	22	-0.00041	0.029	0.010	0.0083	0.0082

¹STORET.

²Calculated from this study.

CHROMIUM (Cr)

Four years of historical data for dissolved chromium were found for Lake Superior waters (Table 32). Except for 1968, all historical data means are quite similar to the 1983 results. However, the 1983 median is lower than all historical data.

Table 32. Dissolved chromium concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1968 ¹	54-61	0.	18.	--	--	1.
1970 ²	--	--	--	<1.	--	--
1970 ³	--	--	--	<0.2	--	--
1971 ²	--	--	--	0.3	0.5	--
1971 ³	--	--	--	<0.20-0.27	--	--
1971 ⁴	32	0.10	2.8	0.52	0.57	0.40
1973 ²	700	--	--	0.1	0.1	0.1
1973 ³	--	--	--	<0.20-0.25	--	--
1983 ⁵	22	0.0023	0.90	0.22	0.26	0.080

¹Weiler and Chawla (1969), filtered and unfiltered results combined.

²Weiler (1978).

³IJC (1977), Michigan Department of Natural Resources and STORET data.

⁴STORET.

⁵This study.

The 1983 median particulate chromium concentration in Lake Superior waters was 0.016 ppb (Table 33). Slightly more than one-third of the analyses were below the limit of detection. No historical particulate chromium data were found.

Table 33. Particulate chromium concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1983 ¹	22	0.0	0.046	0.011	0.011	0.0065

¹This study.

Historical data for total chromium were found for 1968 (Table 34). The calculated 1983 median total chromium concentration of 0.091 ppb is considerably lower than the 1968 median, suggesting limit of detection problems for the 1968 data and rendering the 1968 data useless for studying trends.

Table 34. Total chromium concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1968 ¹	54-61	0.	18.	--	--	1.
1984 ²	22	0.012	0.91	0.24	0.26	0.091

¹Weiler and Chawla (1969), filtered and unfiltered results combined.

²Calculated from this study.

COPPER (Cu)

Six years of historical data on dissolved copper were identified (Table 35). Like cadmium and cobalt, the historical values for dissolved copper concentrations are unreliable for assessing trends. Except for the 1973 and 1976 data, the historical data minimums are above the maximum for 1983, suggesting too high a limit of detection for use of the data for assessing trends. The only data set complete enough for comparison is that of 1976. Concentrations in 1976 were higher than those of 1983.

Table 35. Dissolved copper concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1968 ¹	54-61	4.	230.	--	--	12.
1970 ²	--	--	--	1.8-2.1		--
1970 ³	--	--	--	3.	2.	--
1970 ⁴	18	1.0	17.	2.8	3.7	2.0
1971 ²	--	--	--	2.0-7.0	--	--
1971 ³	--	--	--	7.8	6.9	--
1971 ⁴	50	1.0	41.	7.7	6.3	6.0
1973 ²	--	--	--	0.72-5.0	--	--
1973 ³	682	--	--	2.3	1.7	2.0
1973-4 ⁵	13	0.5	<1.6	0.98	0.34	--
1976 ²	--	--	--	0.95	--	--
1976 ⁴	38	0.50	1.5	0.99	0.18	1.0
1983 ⁶	22	0.58	1.0	0.74	0.10	0.71

¹Weiler and Chawla (1969), filtered and unfiltered results combined.

²IJC (1977), Michigan Department of Natural Resources and STORET data.

³Weiler (1978).

⁴STORET.

⁵Calculated from means for various coastal and embayment sites given in IJC (1977).

⁶This study.

Historical data on particulate copper for water were found for only one year (Table 36). The median for 1983 of 0.12 ppb is higher than that for 1977; however, there is no significance difference between the means of the two years.

Table 36. Particulate copper concentrations (ppb) in Lake Superior epilimnetic water.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1977 ¹	7	0.06	2.4	0.44	0.87	0.08
1983 ²	22	0.049	1.0	0.16	0.20	0.12

¹Eisenreich (1982).

²This study.

Three years of total copper data were found for Lake Superior water (Table 37). The 1963 data are biased high due to a relatively high limit of detection or sample contamination. Likewise, the 1970 median and mean concentrations are similarly biased high due to a relatively high limit of detection. The historical data are of limited usefulness for assessing total copper trends.

Table 37. Total copper concentrations (ppb) in Lake Superior epilimnetic water.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1968 ¹	54-61	4.	230.	--	--	12.
1970 ²	8	1.0	15.	3.4	4.8	1.0
1975 ³	--	--	--	1.5	0.4	--
1983 ⁴	22	0.68	2.0	0.91	0.26	0.89

¹Weiler and Chawla (1969), filtered and unfiltered results combined.

²STORET.

³Poldoski et al. (1978), nearshore (2,500 m) waters.

⁴Calculated from this study.

IRON (Fe)

Lake Superior historical data for dissolved iron were found for five years (Table 38). The 1970 means and median are considerably higher than those of post-1970. The 1976 and 1983 data sets are quite similar to one another.

Table 38. Dissolved iron concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1970 ¹	--	--	--	7.	5.	--
1970 ²	--	--	--	4.8-5.8	--	--
1970 ³	17	2.0	10.	4.6	2.7	5.0
1971 ¹	--	--	--	0.3	8.2	--
1971 ²	--	--	--	1.7-3.0	--	--
1971 ³	48	0.30	38.	2.6	5.4	1.6
1973 ¹	617	--	--	2.1	2.2	1.5
1973 ²	--	--	--	1.1-3.1	--	--
1973-4 ⁴	16	<0.5	6.6	1.4	1.5	--
1974 ³	1	250.	250.	--	--	--
1976 ²	--	--	--	1.2	--	--
1976 ³	38	0.50	3.0	0.83	0.63	0.50
1983 ⁵	22	0.30	6.3	1.1	1.4	0.62

¹Weiler (1978).

²IJC (1977), Michigan Department of Natural Resources and STORET data.

³STORET.

⁴Calculated from means for various coastal and embayment sites given in IJC (1977).

⁵This study.

Historical particulate data were found for one year (Table 39). The 1977 median concentration is considerably higher than that of 1983. The difference between the two years is most likely related to differences in sampling regimes. The differences between means are not statistically significant.

Table 39. Particulate iron concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1977 ¹	7	11.	439.	14.	16.	58.
1983 ²	22	0.45	31.	4.0	6.3	2.0

¹Eisenreich (1982).

²This study.

Historical total iron data for Lake Superior epilimnetic water were available for four periods of time (Table 40). Though not statistically significant, mean concentrations have been decreasing steadily since 1973, and the median concentration has decreased since 1968.

Table 40. Total iron concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1968 ¹	54-61	3.	230.	--	--	8.
1973-4 ²	12	5.2	46.	18.	14.	--
1975 ³	--	--	--	16.	15.	--
1977 ⁴	7	1.8	25.	9.9	9.4	5.3
1983 ⁵	22	1.0	37.	5.1	7.5	2.5

¹Weiler and Chawla (1969).

²Calculated from means for various coastal and embayment sites given in IJC (1977).

³Poldoski et al. (1978), nearshore (2,500 m) waters.

⁴Eisenreich (1982).

⁵Calculated from this study.

MERCURY (Hg)

Dissolved mercury data were found for only two years (Table 41). The 1970 data were all below the limit of detection. The 1971 median concentration is considerably higher than that for 1983.

Table 41. Dissolved mercury concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1970 ¹	—	—	—	<1.	—	—
1971 ²	48	0.050	1.1	0.31	0.26	0.27
1983 ³	22	-0.031	0.056	0.00091	0.018	0.0

¹Weiler (1978).

²STORET.

³This study.

For 1983, particulate mercury concentrations were calculated from the total minus dissolved measured concentrations. The median particulate concentration for 1983 was 0.0010 ppb (Table 42).

Table 42. Calculated particulate mercury concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1983 ¹	22	-0.030	0.10	0.0076	0.034	0.0010

¹This study.

Total mercury data for Lake Superior waters were found for two years (Table 43). Concentrations in 1983 were considerably lower than those of 1970 and 1973.

Table 43. Total mercury concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1970 ¹	--	--	--	<0.05	--	--
1970-1 ²	226	0.0	0.47	0.18	0.13	--
1973 ¹	--	--	--	0.05-0.10	--	--
1973 ³	118	--	--	0.1	0.0	0.1
1973-4 ¹	12	<0.02	<0.04	<0.02	--	--
1983 ⁴	22	-0.023	0.12	0.0098	0.034	0.0020

¹IJC (1977), Michigan Department of Natural Resources and STORET data.

²Chau and Saitoh (1973), samples from all depths.

³Weiler (1978).

⁴This study.

LITHIUM (Li)

Historical data for dissolved lithium were found for only one year (Table 44). The 1971 median concentration is somewhat higher than that of 1983. However, the standard deviations of the two data sets overlap, suggesting no statistically significant difference between the two years.

Table 44. Dissolved lithium concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1971 ¹	50	0.10	1.3	0.73	0.19	0.80
1971 ²	--	--	--	0.8	0.1	--
1983 ³	22	0.56	0.70	0.63	0.039	0.62

¹STORET.

²Weiler (1978).

³This study.

No particulate or total lithium historical data could be found for Lake Superior epilimnetic waters. The median particulate concentration for 1983 was negative because the majority of total lithium was within the dissolved fraction (Table 45). The calculated median total lithium concentration for 1983 was 0.64 ppb (Table 46).

Table 45. Particulate lithium concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1983 ¹	22	-0.0062	0.013	0.0014	0.0015	-0.00044

¹This study.

Table 46. Calculated total lithium concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1983 ¹	22	0.56	0.71	0.63	0.040	0.64

¹This study.

MANGANESE (Mn)

Five years of dissolved manganese data were identified for Lake Superior waters (Table 47). The 1970, 1971, 1973, and 1973-4 historical data appear to be of high quality. The usefulness of the 1968 and 1970 (STORET), and 1974 (STORET) data is limited by probable high detection limits. The 1983 mean and median concentrations were lowest relative to the other years.

Table 47. Dissolved manganese concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1968 ¹	54-61	0.0	1.0	--	--	<1.
1970 ²	3	1.0	3.0	1.7	1.1	1.0
1970 ³	--	--	--	<0.20-0.33	--	--
1971 ²	44	0.10	1.7	0.38	0.30	0.30
1971 ⁴	--	--	--	0.3	0.2	--
1971 ³	--	--	--	0.28-0.40	--	--
1973 ³	--	--	--	<0.20-0.43	--	--
1973 ⁴	575	--	--	0.4	0.4	0.3
1973-4 ⁵	9	<0.05	0.5	0.22	0.14	--
1974 ²	1	10.	10.	--	--	--
1983 ⁶	22	0.046	0.36	0.13	0.079	0.11

¹Weiler and Chawla (1969), filtered and unfiltered results combined.

²STORET.

³IJC (1977), Michigan Department of Natural Resources and STORET data.

⁴Weiler (1978).

⁵Calculated from means for various coastal and embayment sites given in IJC (1977).

⁶This study.

Historical values for particulate manganese concentrations in water were found for one year (Table 48). The 1983 median is less than that for 1977.

Table 48. Particulate manganese concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1977 ¹	7	0.10	9.1	2.3	3.2	1.1
1983 ²	22	0.027	1.0	0.19	0.19	0.16

¹Eisenreich (1982).

²This study.

Historical data for total manganese concentrations in Lake Superior epilimnetic waters were found during five periods of time (Table 49). The 1968 data are of limited usefulness because of detection limit problems, and the 1970 data represent only one measurement. The 1977 data are high compared to those of 1973-4, 1975, and 1983. The 1973-4 and 1975 concentrations are quite similar. They are higher than that for 1983.

MOLYBDENUM (Mo)

Three years of historical data were found for dissolved molybdenum (Table 50). Of these, the 1970 data are below the limit of detection. The 1983 mean and median are below those for 1971 and 1973.

No historical data for particulate or total molybdenum could be found for Lake Superior epilimnetic waters. The 1983 median particulate concentration was 0.0056 ppb (Table 51). The 1983 calculated median total molybdenum concentration was 0.15 ppb (Table 52).

Table 49. Total manganese concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1968 ¹	54-61	0.0	1.0	--	--	<1.
1970 ²	1	1.0	1.0			
1973-4 ³	12	0.3	1.4	0.63	0.27	--
1975 ⁴	--	--	--	0.6	0.2	--
1977 ⁵	7	1.3	13.	5.6	5.1	2.2
1983 ⁶	22	0.14	1.3	0.32	0.24	0.26

¹Weiler and Chawla (1969), filtered and unfiltered results combined.

²STORET.

³Calculated from means for various coastal and embayment sites given in IJC (1977).

⁴Poldoski et al. (1978), nearshore (2,500 m) waters.

⁵Eisenreich (1982).

⁶Calculated from this study.

Table 50. Dissolved molybdenum concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1970 ¹	--	--	--	<1.	--	--
1971 ¹	--	--	--	0.2	0.1	--
1971 ²	40	0.10	0.90	0.30	0.20	0.20
1973 ¹	--	--	--	0.2	0.1	--
1983 ³	22	0.089	0.26	0.14	0.041	0.14

¹Weiler (1978).

²STORET.

³This study.

Table 51. Particulate molybdenum concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1983 ¹	22	0.0025	0.015	0.0071	0.0034	0.0056

¹This study.

Table 52. Calculated total molybdenum concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1983 ¹	22	0.094	0.26	0.15	0.042	0.15

¹This study.

NICKEL (Ni)

Seven years of historical data for dissolved nickel were identified for Lake Superior (Table 53). Excluding 1977, all historical values are greater than those of 1983. The usefulness of the historical data, except 1977, appears limited because of relatively high detection limits. These data should not be used to calculate trends.

Historical data for particulate nickel concentrations were found for one year (Table 54). The 1977 mean and median concentrations are considerably higher than those for 1983.

Table 53. Dissolved nickel concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1968 ¹	--	0.	9.	--	--	2.
1970 ²	--	--	--	<1.	--	--
1970 ³	3	1.0	1.0	1.0	0.0	1.0
1971 ²	--	--	--	1.0	--	--
1971 ³	43	0.20	10.	1.6	1.7	1.0
1971 ⁴	--	--	--	<1.0-1.3	--	--
1973 ²	670	--	--	1.6	1.8	1.0
1973 ⁴	--	--	--	<1.0-3.8	--	--
1973-4 ⁵	12	<0.8	<0.8	<0.8	0.0	--
1976 ⁴	--	--	--	1.0	--	--
1976 ³	38	1.0	1.0	1.0	0.0	1.0
1977 ⁶	7	0.01	0.04	0.014	0.011	0.01
1983 ⁷	22	.0014	0.25	0.048	0.050	0.032

¹Weiler and Chawla (1969); filtered and unfiltered samples combined.

²Weiler (1978).

³STORET.

⁴IJC (1977), Michigan Department of Natural Resources and STORET data.

⁵Calculated from means for various coastal and embayment sites given in IJC (1977).

⁶Eisenreich (1982).

⁷This study.

Total nickel concentration data were identified for three years (Table 55). The mean and median historical concentrations are considerably higher than those for 1983.

Table 54. Particulate nickel concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1977 ¹	7	0.02	1.7	0.57	0.60	0.4
1983 ²	22	-0.0075	0.062	0.018	0.017	0.014

¹Eisenreich (1982).

²This study.

Table 55. Total nickel concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1968 ¹	--	0.	9.	--	--	2.
1970 ²	3	1.0	2.0	1.3	0.58	1.0
1977 ³	5	<3.	5.4	4.4	0.74	4.5
1983 ⁴	22	0.018	0.24	0.066	0.047	0.058

¹Weiler and Chawla (1969); filtered and unfiltered samples combined.

²STORET.

³Eisenreich (1982).

⁴Calculated from this study.

LEAD (Pb)

Six years of historical data for dissolved lead were found (Table 56). Because all historical data appear to have high limits of detection and minima higher than the 1983 maximum, they should not be used for calculation of trends.

Table 56. Dissolved lead concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1968 ¹	54-61	1.	7.	--	--	2.2
1970 ²	--	--	--	2.	2.	--
1970 ³	--	--	--	1.5-1.8	--	--
1970 ⁴	18	1.0	4.0	1.8	1.1	1.0
1971 ²	--	--	--	1.4	0.7	--
1971 ³	--	--	--	1.2-1.4	--	--
1971 ⁴	48	0.50	8.0	1.8	1.6	1.3
1973 ²	684	--	--	0.8	0.9	0.6
1973 ³	--	--	--	<1.0-1.8	--	--
1973-4 ⁵	13	<0.2	0.4	0.2	0.06	--
1976 ³	--	--	--	1.0	--	--
1976 ⁴	38	1.0	1.0	1.0	0.0	1.0
1983 ⁶	22	-0.023	0.10	0.014	0.031	0.0060

¹Weiler and Chawla (1969), filtered and unfiltered results combined.

²Weiler (1978).

³IJC (1977), Michigan Department of Natural Resources and STORET data.

⁴STORET.

⁵Calculated from means for various coastal and embayment sites given in IJC (1977).

⁶This study.

Historical particulate lead data for Lake Superior water were found for only one year (Table 57). The 1977 mean and median concentrations are considerably higher than those for 1983.

Total lead data were found for six years (Table 58). Because the means and medians of all historical data are greater than the maximum concentration for 1983, the historical data should not be used for calculating trends. A combination of relatively high detection limits and sample contamination are probably responsible for the poor quality of the historical data.

Table 57. Particulate lead concentrations (ppb) in Lake Superior epilimnetic water.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1977 ¹	7	0.05	4.7	0.77	1.7	0.1
1983 ²	22	0.011	0.048	0.025	0.010	0.023

¹Eisenreich (1982).

²This study.

Table 58. Total lead concentrations (ppb) in Lake Superior epilimnetic water.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1968 ¹	--	1.	7.	--	--	2.2
1970 ²	8	1.0	3.0	1.4	0.74	1.0
1973-4 ³	14	<0.2	<0.6	0.35	0.12	--
1975 ⁴	--	--	--	0.4	0.2	--
1977 ⁵	7	<0.3	3.2	1.5	1.3	1.5
1983 ⁶	22	-0.0068	0.13	0.039	0.034	0.029

¹Weiler and Chawla (1969), filtered and unfiltered results combined.

²STORET.

³Calculated from means for various coastal and embayment sites given in IJC (1977).

⁴Poldoski et al. (1978), nearshore (waters within 2,500 m of shore).

⁵Eisenreich (1982).

⁶Calculated from this study.

ANTIMONY (Sb)

No historical dissolved, particulate, or total antimony data for Lake Superior waters could be found. The 1983 medians for dissolved and particulate concentrations were 0.082 and -0.102 ppb (below the limit of detection), respectively (Tables 59-60). The calculated median total antimony concentration for 1983 is 0.072 ppb (Table 61).

Table 59. Dissolved antimony concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1983 ¹	22	-0.11	0.21	0.10	0.070	0.082

¹This study.

Table 60. Particulate antimony concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1983 ¹	22	-0.044	-0.0043	-0.014	0.0082	-0.012

¹This study.

Table 61. Calculated total antimony concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1983 ¹	22	-0.12	0.19	0.086	0.066	0.072

¹This study.

SELENIUM (Se)

The 1983 median dissolved selenium concentration was 0.071 ppb (Table 62). No historical data could be found. Roughly one-third of the 1983 analyses were below the limit or criterion of detection.

No particulate or total selenium data could be found. The median particulate and total concentrations in 1983 were 0.048 and 0.12 ppb (Tables 63-64). The majority of 1983 particulate analyses were below the limit or criterion of detection.

Table 62. Dissolved selenium concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1983 ¹	22	-0.040	0.14	0.067	0.043	0.071

¹This study.

Table 63. Particulate selenium concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1983 ¹	22	-0.026	0.14	0.051	0.042	0.048

¹This study.

Table 64. Calculated total selenium concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1983 ¹	22	0.0096	0.24	0.12	0.057	0.12

¹This study.

TIN (Sn)

No historical dissolved, particulate, or total tin data could be found for Lake Superior water. Nearly all of the analyses for dissolved tin were below the limit or criterion of detection (Table 65). All of the analyses for particulate tin were below the limit or criterion of detection (Table 66).

Table 65. Dissolved tin concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1983 ¹	20	-0.0054	0.0086	0.0015	0.0035	0.00080

¹This study.

Table 66. Particulate tin concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1983 ¹	22	-0.96	-0.040	-0.72	0.20	-0.75

¹This study.

STRONTIUM (Sr)

Two years of dissolved strontium data were found for Lake Superior waters (Table 67). All historical data are useful for assessing trends. The 1983 median is higher than those for the previous years.

No historical data for particulate strontium could be found for Lake Superior water. The median for 1983 was below the limit of detection (Table 68). Nearly all of the analyses were below the criterion or limit of detection.

Historical total strontium data were found only for 1968 (Table 69). The ranges in concentration observed for 1968 and 1983 are quite similar. The 1983 median concentration is considerably higher than that of 1968.

Table 67. Dissolved strontium concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1968 ¹	54-61	30.	70.	--	--	32.
1971 ²	--	--	--	29.	8.	--
1971 ³	46	15.	47.	32.	8.	34.
1983 ⁴	22	33.	64.	44.	7.5	42.

¹Weiler and Chawla (1969), filtered and unfiltered results combined.

²Weiler (1978).

³STORET.

⁴This study.

Table 68. Particulate strontium concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1983 ¹	22	-0.057	0.055	-0.012	0.031	-0.022

¹This study.

Table 69. Total strontium concentrations (ppb) in Lake Superior epilimnetic water.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1968 ¹	--	30.	70.	--	--	32.5
1983 ²	22	33.	64.	44.	7.5	42.

¹Weiler and Chawla (1969), filtered and unfiltered results combined.

²Calculated from this study.

VANADIUM (V)

Historical data for dissolved vanadium in Lake Superior waters were found for two years (Table 70). The 1970 and 1971 data were below the limit of detection. The 1983 median concentration was 0.31 ppb.

The 1983 median particulate vanadium concentration in water was 0.018 ppb (Table 71). Approximately one-third of the analyses were below the limit of detection. No historical particulate data could be found.

Historical total vanadium data were found for one year (Table 72). The 1983 mean and median are considerably larger than those for 1971.

Table 70. Dissolved vanadium concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1970 ¹	--	--	--	<1.	--	--
1971 ¹	--	--	--	0.	0.1	--
1983 ²	22	0.15	0.68	0.35	0.12	0.31

¹Weiler (1978).

²This study.

Table 71. Particulate vanadium concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1983 ¹	22	0.00050	0.064	0.011	0.013	0.0080

¹This study.

Table 72. Total vanadium concentrations (ppb) in Lake Superior epilimnetic water.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1971 ¹	6	0.10	0.40	0.23	0.10	0.20
1983 ²	22	0.15	0.69	0.36	0.12	0.32

¹STORET.

²Calculated from this study.

ZINC (Zn)

Lake Superior dissolved zinc data were found for six years (Table 73). All historical data are considerably higher than those of 1983. The historical data are apparently of poor quality because of sample contamination and high detection limits. These data should not be used to calculate trends.

Historical data for particulate zinc in Lake Superior water were found for only one year (Table 74). The 1977 mean and median concentrations are considerably higher than those found for 1983.

Five years of historical data for total zinc in lake water were found (Table 75). The 1983 median and mean concentrations are much lower than those for the other years. The historical minimum concentrations exceed or are only slightly less than the maximum for 1983. Thus, the historical data are considered to be of poor quality, and trends should not be derived from them.

Table 73. Dissolved zinc concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1968 ¹	54-61	9.0	80.	--	--	27.
1970 ²	--	--	--	5.	2.	--
1970 ³	--	--	--	4.5	--	--
1970 ⁴	8	4.0	9.0	5.8	1.8	6.0
1971 ²	--	--	--	13.	9.6	--
1971 ³	--	--	--	4.1-14.	--	--
1971 ⁴	48	1.0	37.	13.	8.8	10.
1973 ²	659	--	--	14.	11.2	11.
1973 ³	--	--	--	8.0-26.	--	--
1973-4 ⁵	5	0.7	<4.0	2.0	1.4	--
1976 ³	--	--	--	3.3	--	--
1976 ⁴	38	1.0	9.0	4.2	1.8	4.0
1983 ⁶	22	0.20	1.4	0.41	0.30	0.26

¹Weiler and Chawla (1969), filtered and unfiltered results combined.

²Weiler (1978).

³IJC (1977), Michigan Department of Natural Resources and STORET data.

⁴STORET.

⁵Calculated from means for various coastal and embayment sites given in IJC (1977).

⁶This study.

Table 74. Particulate zinc concentrations (ppb) in Lake Superior epilimnetic waters.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1977 ¹	7	0.3	0.9	0.50	0.22	0.4
1983 ²	22	0.011	0.048	0.025	0.010	0.023

¹Eisenreich (1982).

²This study.

Table 75. Total zinc concentrations (ppb) in Lake Superior epilimnetic water.

Year	Number of Samples	Minimum	Maximum	Mean	Standard Deviation	Median
1968 ¹	54-61	9.	80.	--	--	27.0
1970 ²	8	1.0	17.	5.1	5.1	4.0
1973-4 ³	16	<1.0	5.1	2.3	1.1	--
1977 ⁴	7	4.6	31.	14.	12.	12.
1983 ⁵	22	0.29	1.4	0.53	0.31	0.39

¹Weiler and Chawla (1969), filtered and unfiltered results combined.

²STORET.

³Calculated from means for various coastal and embayment sites given in IJC (1977).

⁴Eisenreich (1982).

⁵This study.

WATER QUALITY OBJECTIVES AND OBSERVED METAL CONCENTRATIONS

In order to ascertain whether or not Water Quality Agreement objectives for total metals in water were met in 1983, calculated total and dissolved metal concentrations were compared to the objectives (Table 76). This comparison revealed that only the objective for total lead was exceeded by one sample. That sample is believed to have been contaminated during the collection process.

Table 76. Water Quality Agreement objectives for metal concentrations in Lake Superior waters.

Metal	IJC Objective (ppb) ¹
Total Ag	0.1
Total As	50.
Total Cd	0.2
Total Cr	50.
Total Cu	5.
Total Fe	300.
Dissolved Hg	0.20
Total Ni	25.
Total Pb	2.0
Total Se	1.0 ²
Total Zn	30.

¹International Joint Commission (1978).

²Recommended objective.

POTENTIAL TOXICITY OF METAL MIXTURES

Using the toxicity unit concept recommended and described in an Aquatic Ecosystems Objectives Committee report to the Great Lakes Science Advisory Board of the International Joint Commission (1980), the toxicity unit was calculated for the metals for which water quality objectives exist (Table 77).

Table 77. Toxicity unit results for the waters of Lake Superior in 1983.¹

Metal	M_i/O_i
Ag	0.0
As	0.010
Cd	0.14
Cr	0.0018
Cu	0.18
Fe	0.0083
Hg	0.0
Ni	0.0023
Pb	0.014
Se	0.12
Zn	<u>0.013</u>
$\text{Toxicity Unit} = \sum_{i=1}^n \frac{M_i}{O_i} =$	0.49

¹1983 median concentrations from this study used for calculation.

The toxicity unit is equal to the sum of the ratios of each metal concentration (M_i) to its respective objective concentration (O_i). The sum should not exceed 1.0. When the toxicity unit exceeds 1.0, subtle adverse effects on the biota are expected to occur (IJC 1980). This is not the case for the current objectives for Lake Superior waters. Toxicity units calculated for Lakes Erie, Michigan, and Huron are 3.91, 4.16, and 0.808, respectively (Rossmann 1984b). Thus, Lake Superior waters have the lowest calculated toxicity unit. Metals which significantly impact the calculated Lake Superior toxicity unit are cadmium, copper, and selenium. These metals should be carefully monitored in the future.

REGIONAL VARIATION

For the purpose of investigating east-west variations in metal concentrations, Lake Superior was divided into three regions. The regions are eastern (stations 2, 12, 22, and 25), central (stations 42, 45, 62, 80, 84, 102, 113, 125, 133, 149, 157, and 169), and western (stations 182, 194, 208, and 218). At the 0.05 level of significance, the only statistically significant variation in mean dissolved metal concentrations with region was for copper, mercury, barium, iron, and lithium (Table 78). Eastern Lake Superior dissolved copper and lithium concentrations were significantly higher than those of the central and western regions. Dissolved mercury concentrations in the eastern region were significantly higher than those in the central region. Dissolved barium and iron concentrations in the western region were significantly higher than those of the central region. Though not statistically significant, median dissolved cobalt, mercury, nickel, and selenium concentrations were highest in eastern Lake Superior. Median dissolved aluminum, arsenic, cadmium, molybdenum,

Table 78. Regional variation of dissolved metals (ppb) in 1983 Lake Superior epilimnetic waters.

Metal	Eastern				Central				Western			
	N	Mean	Standard Deviation	Median	N	Mean	Standard Deviation	Median	N	Mean	Standard Deviation	Mean
Ag	4	-0.0015	0.0013	-0.0022	14	-0.0027	0.0014	-0.0032	4	-0.000016	0.0066	-0.0032
Al	4	0.96	1.5	0.45	14	1.8	2.7	1.4	4	2.8	2.6	1.2
As	4	0.45	0.050	0.44	14	0.59	0.14	0.54	4	0.49	0.051	0.48
B	4	-23.	12.	-32.	14	-21.	16.	-27.	4	-24.	15.	-29.
Ba	4	20.	1.6	20.	14	20.	1.8	20.	4	24.	2.8	22.
Be	4	-0.031	0.014	-0.032	14	-0.028	0.013	-0.021	4	-0.034	0.0074	-0.034
Bi	4	-0.032	0.0058	-0.034	14	-0.11	0.052	-0.14	4	-0.14	0.018	-0.15
Cd	4	0.0062	0.0026	0.0050	14	0.0070	0.0025	0.0070	4	0.0055	0.0051	0.0020
Co	4	0.013	0.012	0.0091	14	0.0084	0.0085	0.0057	4	0.011	0.0071	0.0058
Cr	4	0.10	0.066	0.063	14	0.25	0.31	0.057	4	0.27	0.15	0.19
Cu	4	0.92	0.081	0.86	14	0.70	0.059	0.69	4	0.71	0.074	0.68
Fe	4	0.74	0.67	0.34	14	0.65	0.29	0.50	4	3.1	2.4	2.3
Hg	4	0.023	0.023	0.014	14	-0.0058	0.013	-0.0060	4	0.0022	0.012	0.0020
Li	4	0.67	0.035	0.64	14	0.62	0.037	0.62	4	0.60	0.013	0.60
Mn	4	0.17	0.13	0.11	14	0.11	0.044	0.11	4	0.18	0.11	0.14
Mo	4	0.14	0.043	0.12	14	0.15	0.045	0.14	4	0.14	0.031	0.12
Ni	4	0.071	0.0030	0.070	14	0.042	0.060	0.022	4	0.043	0.036	0.032
Pb	4	-0.00075	0.013	-0.0040	14	0.020	0.037	0.0060	4	0.0098	0.0090	0.0050
Sb	4	0.056	0.11	0.082	14	0.10	0.059	0.078	4	0.13	0.044	0.13
Se	4	0.074	0.019	0.071	14	0.064	0.050	0.062	4	0.068	0.044	0.052
Sn	3	-0.0018	0.0032	-0.00050	14	0.0018	0.0032	0.00090	3	0.0035	0.0041	0.0015
Sr	4	41.	10.	34.	14	44.	7.4	42.	4	48.	3.6	46.
V	4	0.42	0.18	0.30	14	0.34	0.12	0.31	4	0.32	0.060	0.31
Zn	4	0.26	0.048	0.24	14	0.44	0.35	0.26	4	0.47	0.25	0.37

and lead concentrations were highest in central Lake Superior, and median dissolved barium, chromium, iron, manganese, antimony, tin, strontium, and zinc were highest in western Lake Superior.

Aluminum, barium, iron, manganese, molybdenum, vanadium, arsenic, and selenium exhibited statistically significant regional variations in particulate concentrations (Table 79). Aluminum, barium, iron, manganese, and vanadium concentrations in the western region were significantly higher than those in the central region. Molybdenum concentrations in the eastern and western regions were significantly higher than those in the central region. Arsenic concentrations were significantly higher in the eastern region than those in the central region, and selenium concentrations were significantly higher in the eastern region than those in the western region. Though not statistically significant, median particulate concentrations of silver, barium, cobalt, iron, and vanadium were highest in western Lake Superior. Similarly, median particulate concentrations of bismuth, chromium, copper, and zinc were highest in central Lake Superior; and median particulate concentrations of arsenic, boron, mercury, lithium, molybdenum, and nickel were highest in eastern Lake Superior.

Statistically significant regional variations were found for total metal concentrations of aluminum, barium, copper, iron, mercury, manganese, and lithium. Calculated total aluminum concentrations were significantly higher in western Lake Superior than those in the eastern and central regions, and calculated total lithium concentrations were significantly higher in the eastern region than those in the western region (Table 80). Barium, iron, and manganese concentrations in the western region were significantly higher than those in the central region; calculated total copper and measured total mercury concentrations in the eastern region were significantly higher than those in the central

Table 79. Regional variation of particulate metals (ppb) in 1983 Lake Superior epilimnetic waters.

Metal	Eastern			Central			Western		
	N	Mean	Standard Deviation	N	Mean	Standard Deviation	N	Mean	Standard Deviation
Ag	4	0.0013	0.00033	0.0011	14	0.0012	0.00059	0.0015	0.00029
Al	4	1.0	1.0	0.66	14	3.1	2.1	11.	8.2
As	4	0.035	0.015	0.036	14	0.0038	0.025	0.011	0.019
B	4	1.7	2.3	0.94	14	1.8	7.0	-0.98	2.9
Ba	4	0.0029	0.062	-0.027	14	0.055	0.063	0.18	0.13
Be	4	-0.0040	0.00065	-0.0042	14	-0.0026	0.0014	-0.0012	-0.00040
Bi	4	0.0038	0.013	0.0035	14	0.0068	0.014	-0.011	0.015
Cd	4	0.016	0.0051	0.016	14	0.020	0.012	0.026	0.0077
Co	4	0.00021	0.00080	0.00040	14	-0.00034	0.0014	0.0030	0.0042
Cr	4	0.010	0.0097	0.035	14	0.0085	0.0067	0.021	0.020
Cu	4	0.33	0.47	0.088	14	0.14	0.058	0.087	0.022
Fe	4	1.5	1.5	0.74	14	2.4	1.7	12.	13.
Hg ¹	4	0.022	0.056	0.0040	12	0.0061	0.027	-0.0018	0.029
Li	4	-0.00027	0.0038	0.00068	14	0.0016	0.0057	0.0023	0.0069
Mn	4	0.16	0.028	0.16	14	0.14	0.068	0.40	0.40
Mo	4	0.010	0.0028	0.0098	14	0.0054	0.0022	0.010	0.0041
Ni	4	0.021	0.011	0.022	14	0.017	0.020	0.018	0.0055
Pb	4	0.022	0.015	0.012	14	0.023	0.0061	0.032	0.016
Sb	4	-0.0099	0.039	-0.011	14	-0.013	0.0056	-0.022	0.015
Se	4	0.091	0.031	0.083	14	0.049	0.041	0.016	0.027
Sn	4	-0.72	0.060	-0.75	14	-0.70	0.24	-0.82	0.11
Sr	4	-0.031	0.019	-0.030	14	-0.012	0.032	0.0034	0.036
V	4	0.0086	0.0073	0.0070	14	0.0082	0.0062	0.025	0.027
Zn	4	0.21	0.28	0.027	14	0.10	0.055	0.098	0.036

1 Calculated particulate concentration.

Table 80. Regional variation of calculated total metals (ppb) in 1983 Lake Superior epilimnetic waters.

Metal	Eastern			Central			Western			
	N	Mean	Standard Deviation	N	Mean	Standard Deviation	N	Mean	Standard Deviation	Mean
Ag	4	-0.00026	0.0012	14	-0.0014	0.0014	4	0.0015	0.0066	-0.0019
Al	4	2.0	1.0	14	4.9	3.2	4	14.	7.5	12.
As	4	0.48	0.049	14	0.59	0.14	4	0.50	0.050	0.52
B	4	-21.	14.	14	-20.	17.	4	-25.	12.	-30.
Ba	4	20.	1.6	14	20.	1.8	4	24.	2.8	22.
Be	4	-0.035	0.014	14	-0.030	0.013	4	-0.035	0.0071	-0.035
Bi	4	-0.028	0.0093	14	-0.10	0.052	4	-0.15	0.024	-0.14
Cd	4	0.023	0.0056	14	0.027	0.012	4	0.031	0.0064	0.028
Co	4	0.013	0.012	14	0.0080	0.0078	4	0.014	0.0052	0.012
Cr	4	0.11	0.075	14	0.26	0.31	4	0.29	0.13	0.22
Cu	4	1.2	0.47	14	0.84	0.10	4	0.79	0.088	0.79
Fe	4	2.2	1.4	14	3.0	1.7	4	15.	15.	7.1
Hg ¹	4	0.044	0.049	12	0.0014	0.026	4	0.00050	0.024	-0.020
Li	4	0.67	0.037	14	0.62	0.038	4	0.60	0.013	0.60
Mn	4	0.33	0.14	14	0.24	0.080	4	0.58	0.50	0.29
Mo	4	0.15	0.046	14	0.15	0.045	4	0.15	0.035	0.13
Ni	4	0.092	0.011	14	0.059	0.055	4	0.061	0.039	0.046
Pb	4	0.021	0.025	14	0.043	0.039	4	0.042	0.017	0.029
Sb	4	0.046	0.11	14	0.091	0.055	4	0.11	0.034	0.12
Se	4	0.16	0.044	14	0.11	0.057	4	0.084	0.050	0.062
Sn	4	-0.74	0.043	14	-0.70	0.25	3	-0.84	0.10	-0.85
Sr	4	41.	10.	14	44.	7.4	4	48.	3.6	46.
V	4	0.43	0.18	14	0.35	0.12	4	0.34	0.068	0.32
Zn	4	0.48	0.25	14	0.54	0.35	4	0.56	0.27	0.45

¹ Measured total concentration.

region. Though not statistically significant, median total concentrations of barium, cobalt, chromium, iron, manganese, antimony, strontium, and zinc were highest in the western region. Likewise, median total concentrations of arsenic, molybdenum, and lead were highest in the central region;, and median total concentrations of copper, mercury, nickel, and selenium were highest in the eastern region.

VERTICAL PROFILES OF DISSOLVED AND PARTICULATE METALS

Introduction

During the collection of 1-m depth water and particulate samples, similar samples were collected from a variety of depths at stations LS-83-62 and LS-83-208. Sample depths were based upon the bathythermograph records at the two stations. The depths sampled were 1 m, 1 m above the knee of the thermocline, mid-thermocline, 1 m below the knee of the thermocline, 10 m above the bottom, and 2 m above the bottom. At station LS-83-208, a 100-m depth sample also was collected. The 1-m samples were collected using the equipment and method already described. The vertical profile samples were collected with a Rosette Sampler on the way up. At station LS-83-208, the 1-m bottle did not trigger and an individual Niskin cast was taken. Thus, both vertical profiles and an intercomparison of sampling techniques were done. Though numerous studies have described metal contamination from bottles used for marine sampling when holding times in the bottles can be many hours, few studies have addressed the contamination of freshwater samples held for a period measured in minutes. The complete dissolved and particulate results are summarized in Appendices 1 and 2, respectively.

Intercomparison of Sampling Techniques

The system designed and used by the author (Rossmann 1982) is constructed entirely of PVC and is capable of being rinsed at the depth of sampling with water from the depth of sampling. With the Rossette sampler, Niskin bottles on a frame are lowered to near the lake bottom, during which time an EBT trace is made. After selection of sampling depths, sampling is done at desired depths on the return trip to the surface. For the Great Lakes, where sampling depths are measured only in hundreds of meters, the time of contact between the Niskin bottle and the sample is less than 1 hour and commonly less than 30 minutes. This is unlike the sampling in the deep ocean where sampled depths can be measured in kilometers, and holding times of samples in the water bottles are measured in hours. Because of the author's past good results with his sampler, the desire was to collect all regular samples with that system. However, that system is currently limited to a maximum sampling depth of roughly 20 m. Thus, for determining vertical profiles of metals, the available Rossette system aboard the CSS Limnos was used.

Those samples (1-m), collected with the Niskin bottles, had consistently higher concentrations of dissolved mercury, dissolved nickel, particulate barium, particulate chromium, particulate molybdenum, particulate nickel, and particulate lead than those collected with Rossmann's system (Appendices 1 and 2). Contamination is postulated to be the result of the Niskin bottles being stored in a contaminated environment, stored for periods of time in the cocked position, lowered into the sediment during sampling, and inadequately flushed after passing through the nephroid layer.

Vertical Profiles

A number of metals varied similarly with depth at both vertical profile stations (LS-83-62 and LS-83-208). For the purposes of this discussion, only those metals which had a significant fraction of the analyses above the criterion of detection are presented. Relatively high concentrations of metals 2 to 10 m above the lake bottom most likely are the result of the presence of a nephloid layer. Elevated epilimnion or surface metal concentrations at LS-83-208 are inferred to be due to erosion of nearby red clay bluffs along the shoreline. The water was discolored brown by the particulate clay. Only the Niskin bottle results are presented; hence, comments regarding sample contamination apply only to those samples collected with Niskin bottles and not to those collected with the system described by Rossmann (1982).

Particulate Silver

There was no consistent vertical variation in particulate silver at the two stations (Fig. 2). The variance of the analyses was too high to allow any conclusions to be made.

Dissolved Arsenic

At both locations, dissolved arsenic concentrations increased with increasing depth (Fig. 3). Because arsenic does not accumulate in bottom sediments, arsenic regenerated from the sediments may be elevating concentrations in the hypolimnion.

Dissolved and Particulate Aluminum

For dissolved aluminum, there was no consistent change in concentration with depth (Fig. 4). At LS-83-62, the high concentration 10 m above the lake

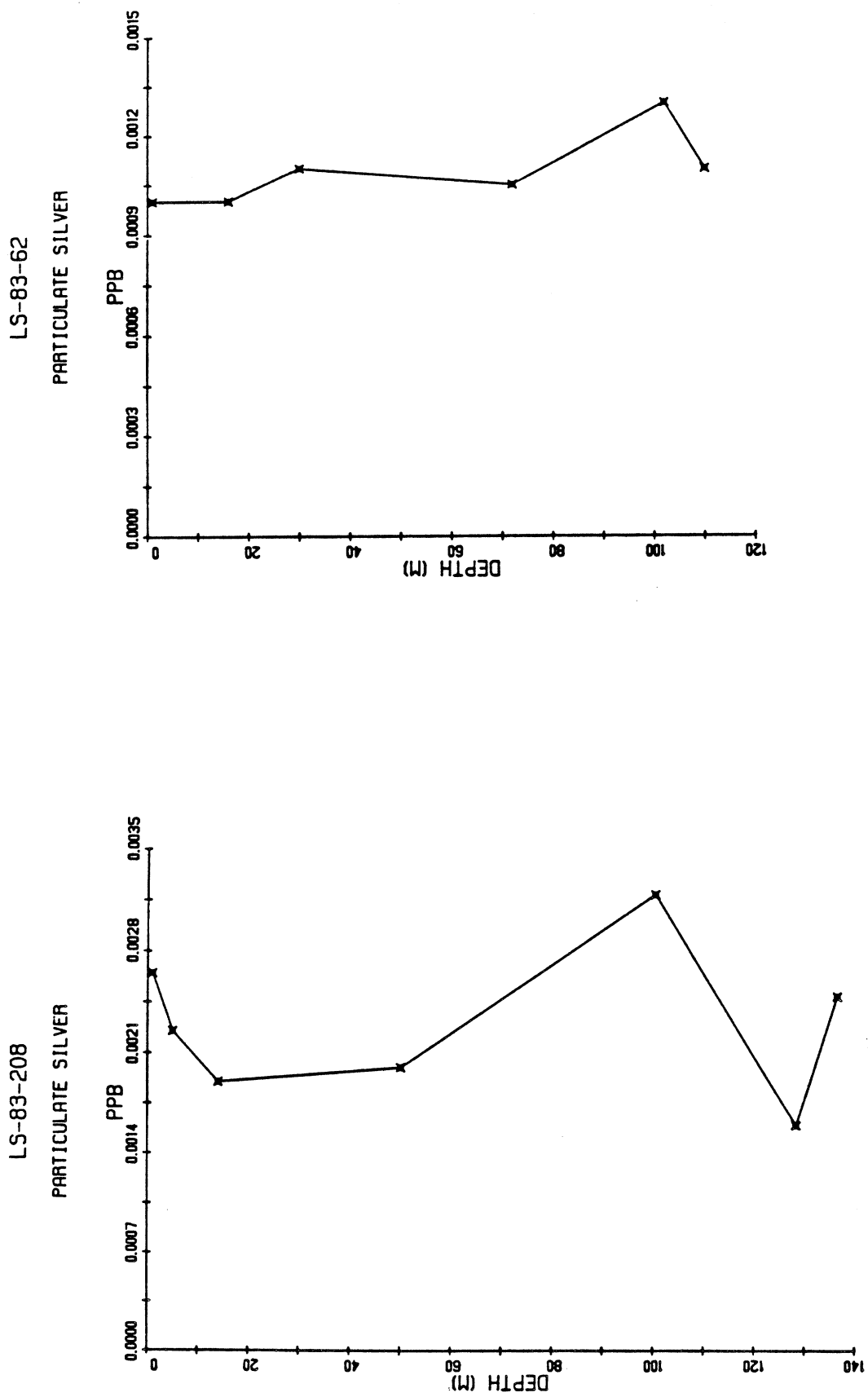
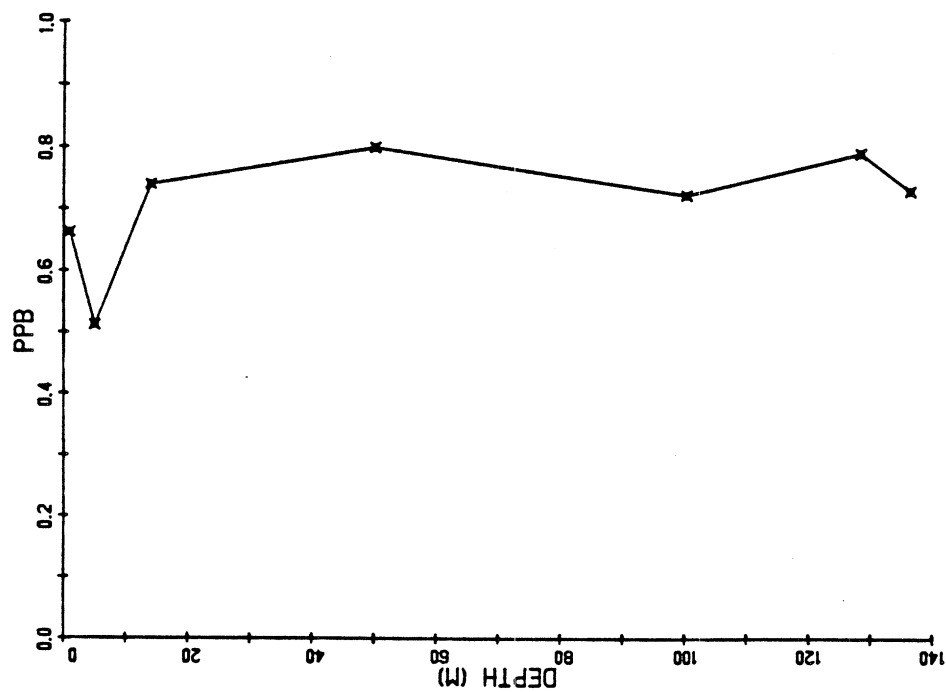


Figure 2. Vertical variation of particulate silver in 1983 Lake Superior water.

LS-83-208

DISSOLVED ARSENIC



LS-83-62

DISSOLVED ARSENIC

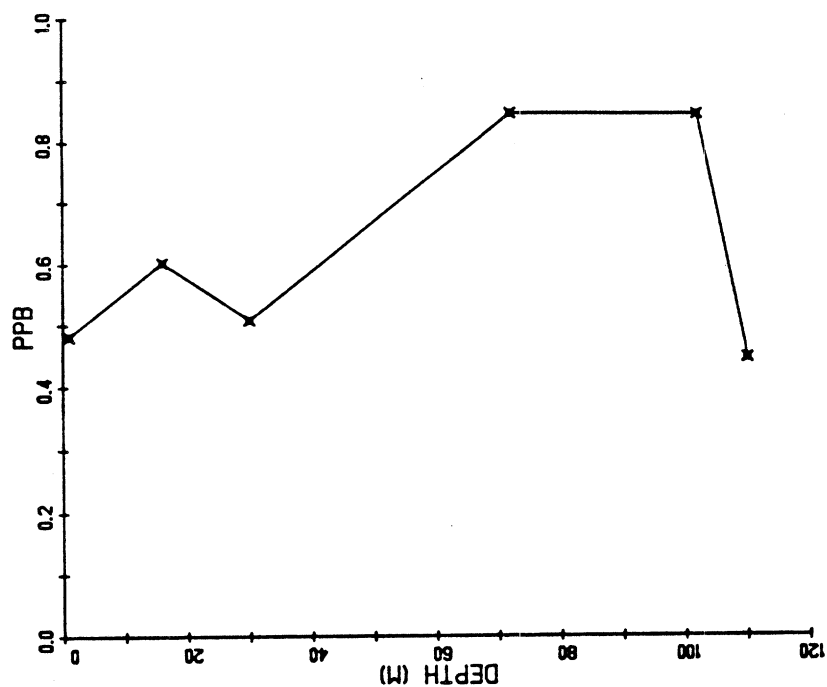
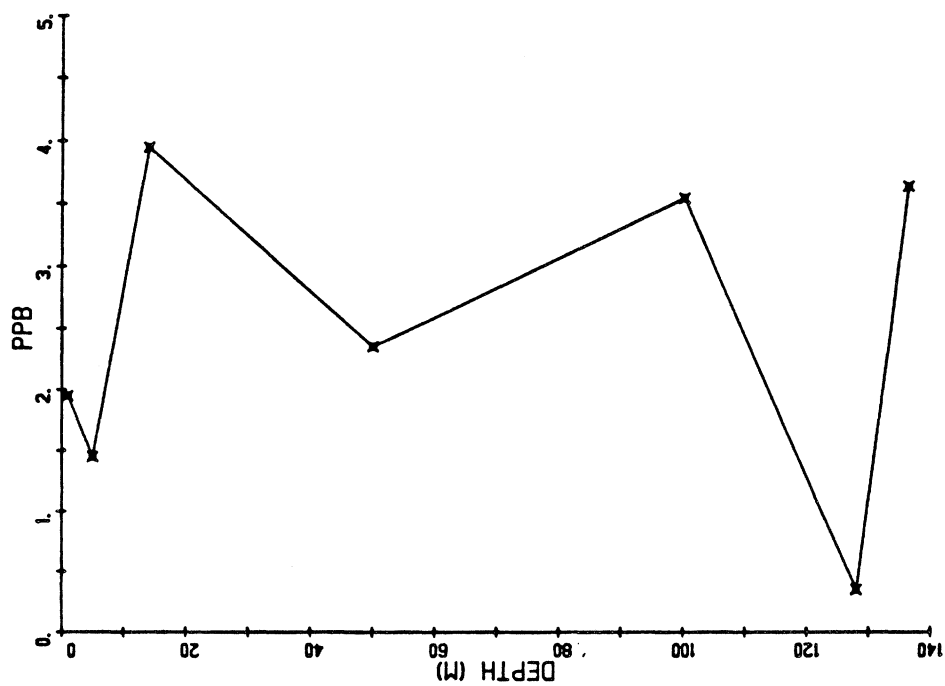


Figure 3. Vertical variation of dissolved arsenic in 1983 Lake Superior water.

LS-83-208

DISSOLVED ALUMINUM



LS-83-62

DISSOLVED ALUMINUM

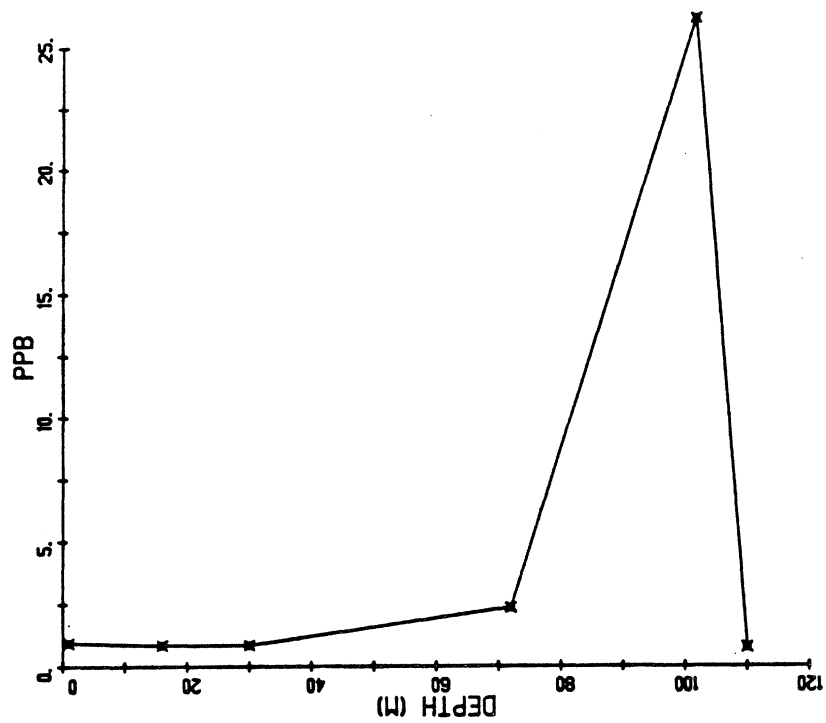


Figure 4. Vertical variation of dissolved aluminum in 1983 Lake Superior water.

bottom may be due to the presence of a nephloid layer. At station LS-83-208, the mean concentration in the epilimnion is less than that of the hypolimnion.

For particulate aluminum, concentrations at mid-thermocline were lower than those in the epilimnion or hypolimnion (Fig. 5). High concentrations near the bottom are indicative of a nephloid layer. Relatively high concentrations in the epilimnion at station LS-83-208 are due to erosion of the nearby shoreline.

Dissolved and Particulate Barium

Near bottom dissolved barium concentrations were lower than those at the surface (Fig. 6). This can be the result of inputs of barium to the lake's surface.

As for the dissolved barium, particulate barium concentrations were highest near the surface (Fig. 7). In the case of particulate barium, the observed concentration differences may be a result of sample contamination during collection.

Particulate Cadmium

There were no consistent significant vertical variations in particulate cadmium at the two sites (Fig. 8). At LS-83-208, epilimnetic concentrations were significantly higher than those from deeper in the water column. This may be a consequence of the eroding of the nearby Lake Superior shoreline.

Dissolved and Particulate Cobalt

For both dissolved and particulate cobalt there was no consistent vertical variation in concentration at the two locations (Figs. 9 and 10). At station LS-83-208, dissolved and particulate epilimnetic cobalt concentrations were significantly higher than those deeper in the water column. This is again attributed to erosion of the nearby shoreline.

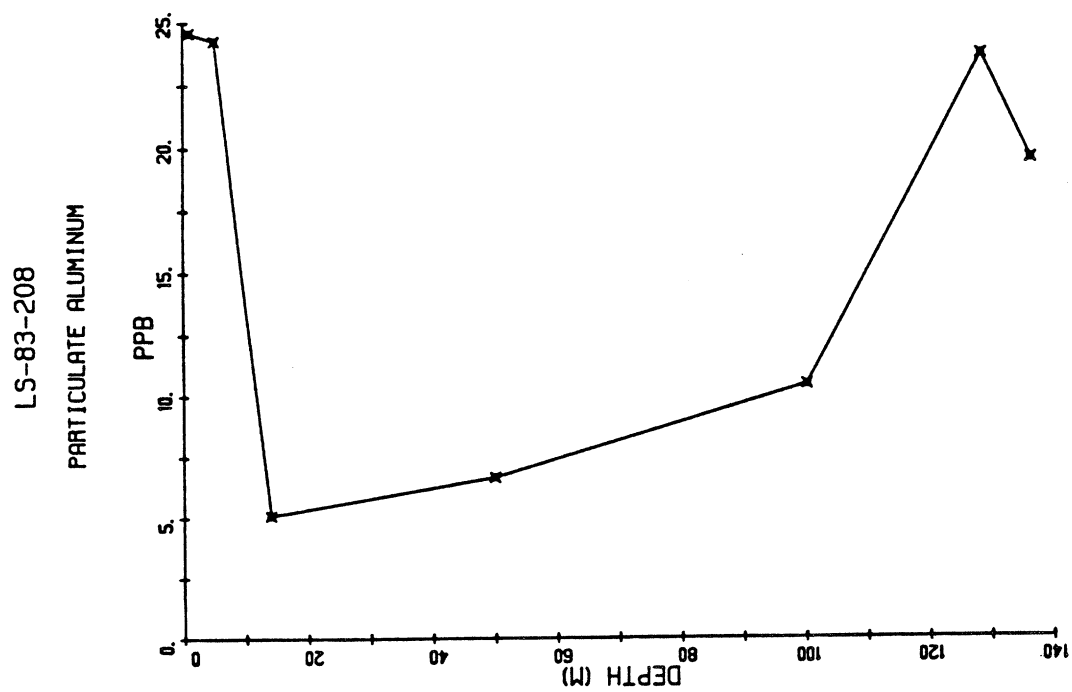
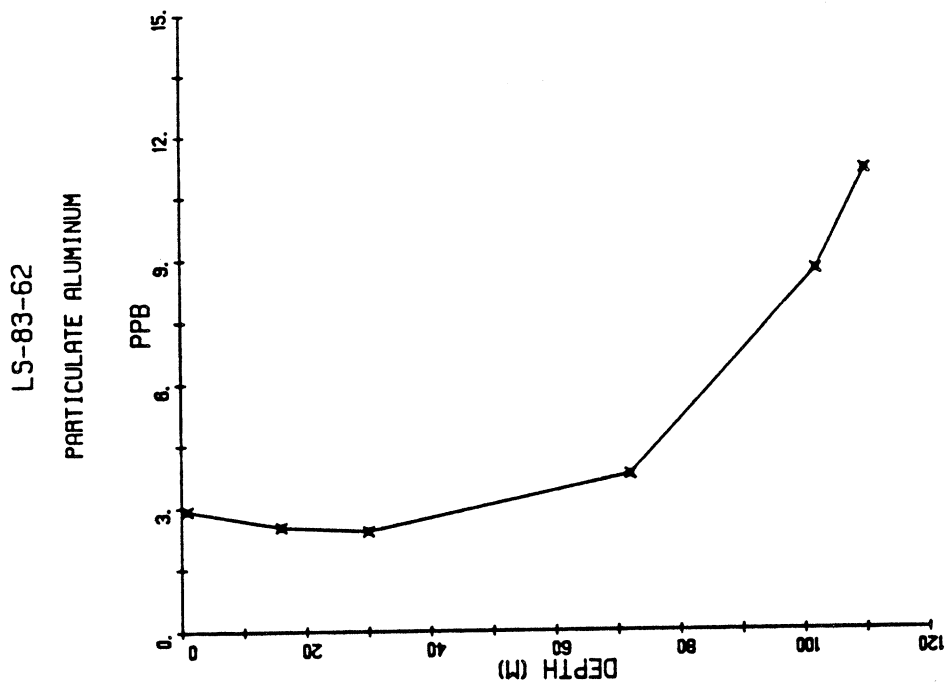


Figure 5. Vertical variation of particulate aluminum in 1983 Lake Superior water.

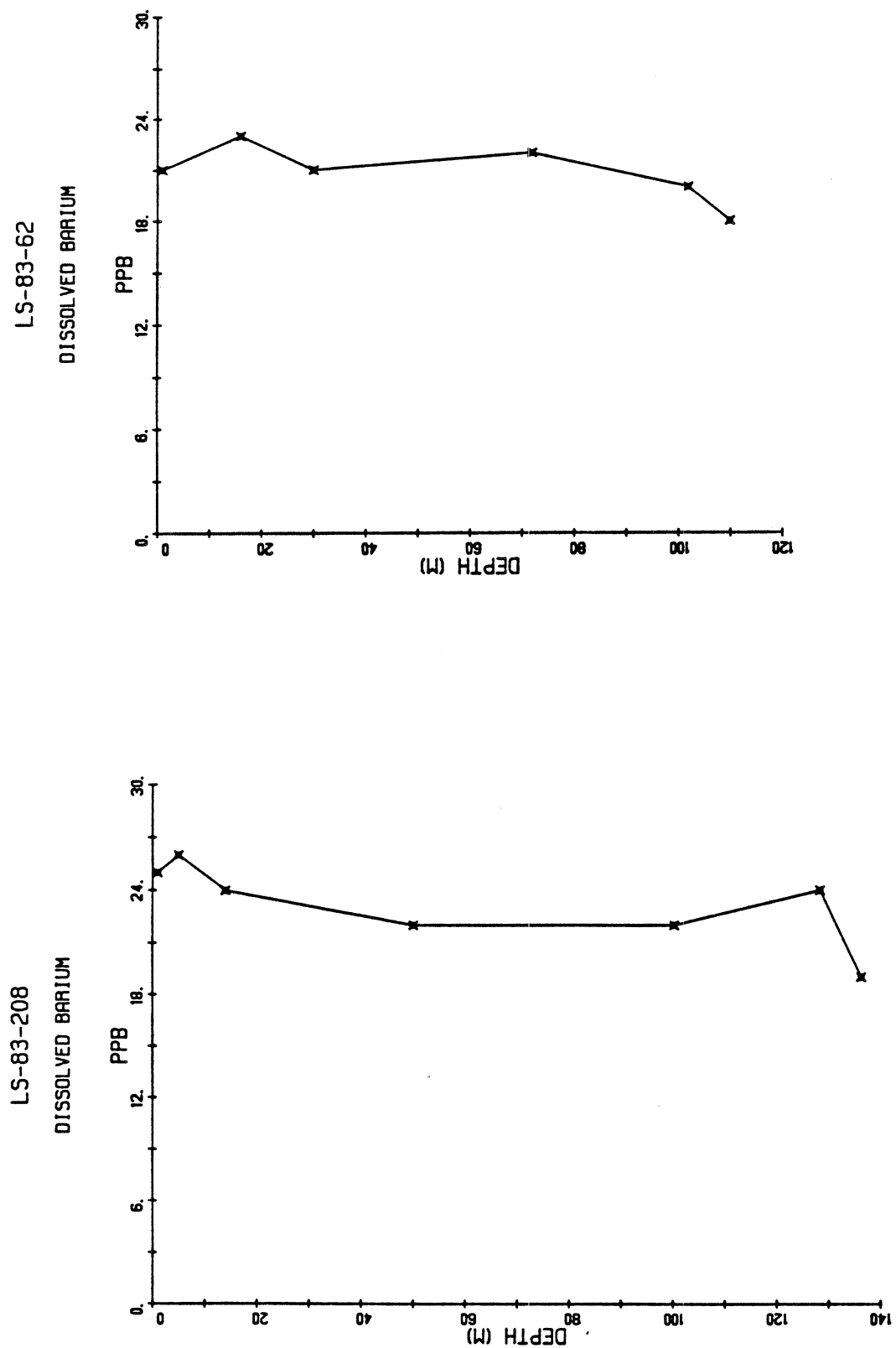


Figure 6. Vertical variation of dissolved barium in 1983 Lake Superior water.

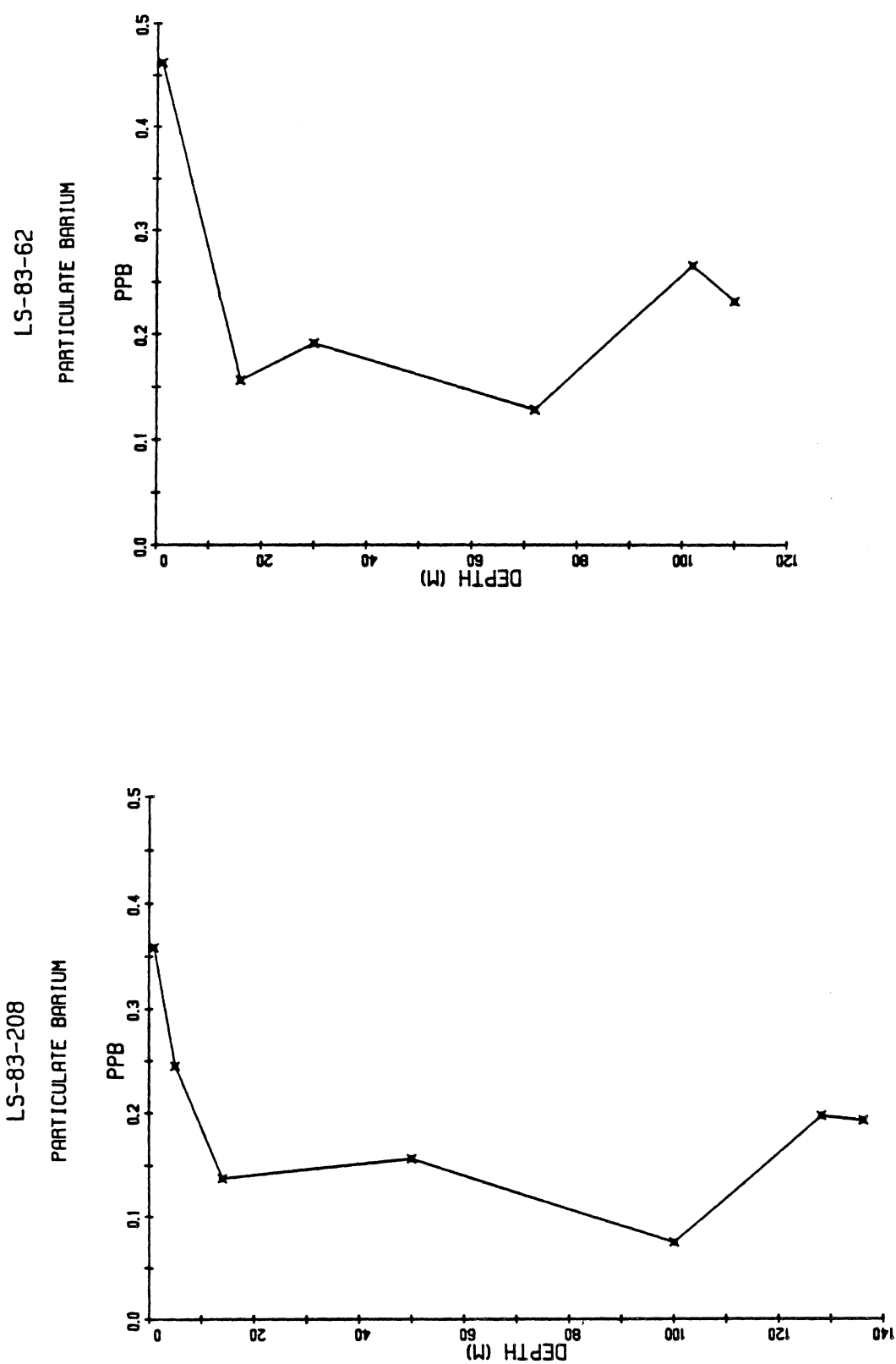


Figure 7. Vertical variation of particulate barium in 1983 Lake Superior water.

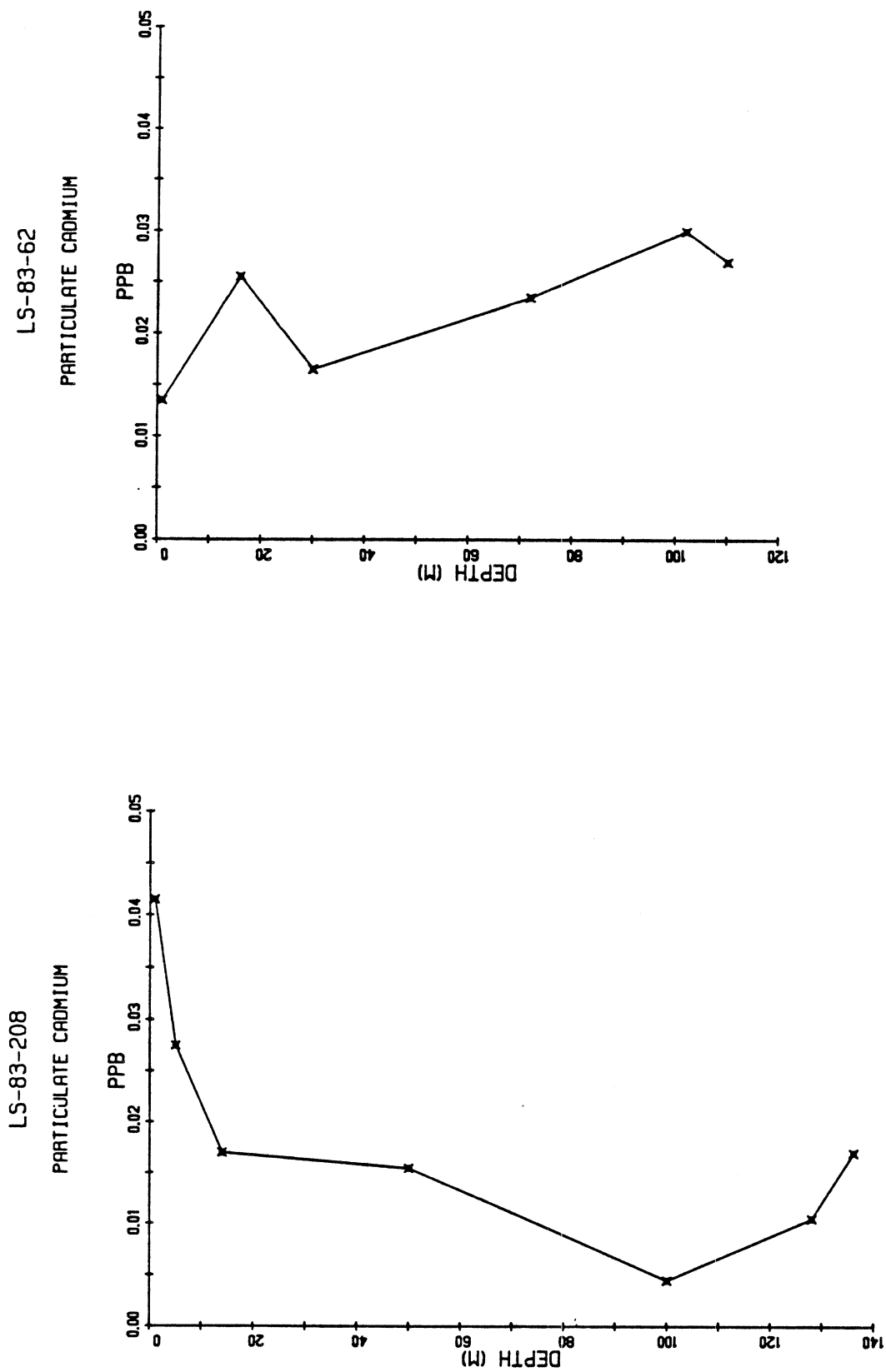


Figure 8. Vertical variation of particulate cadmium in 1983 Lake Superior water.

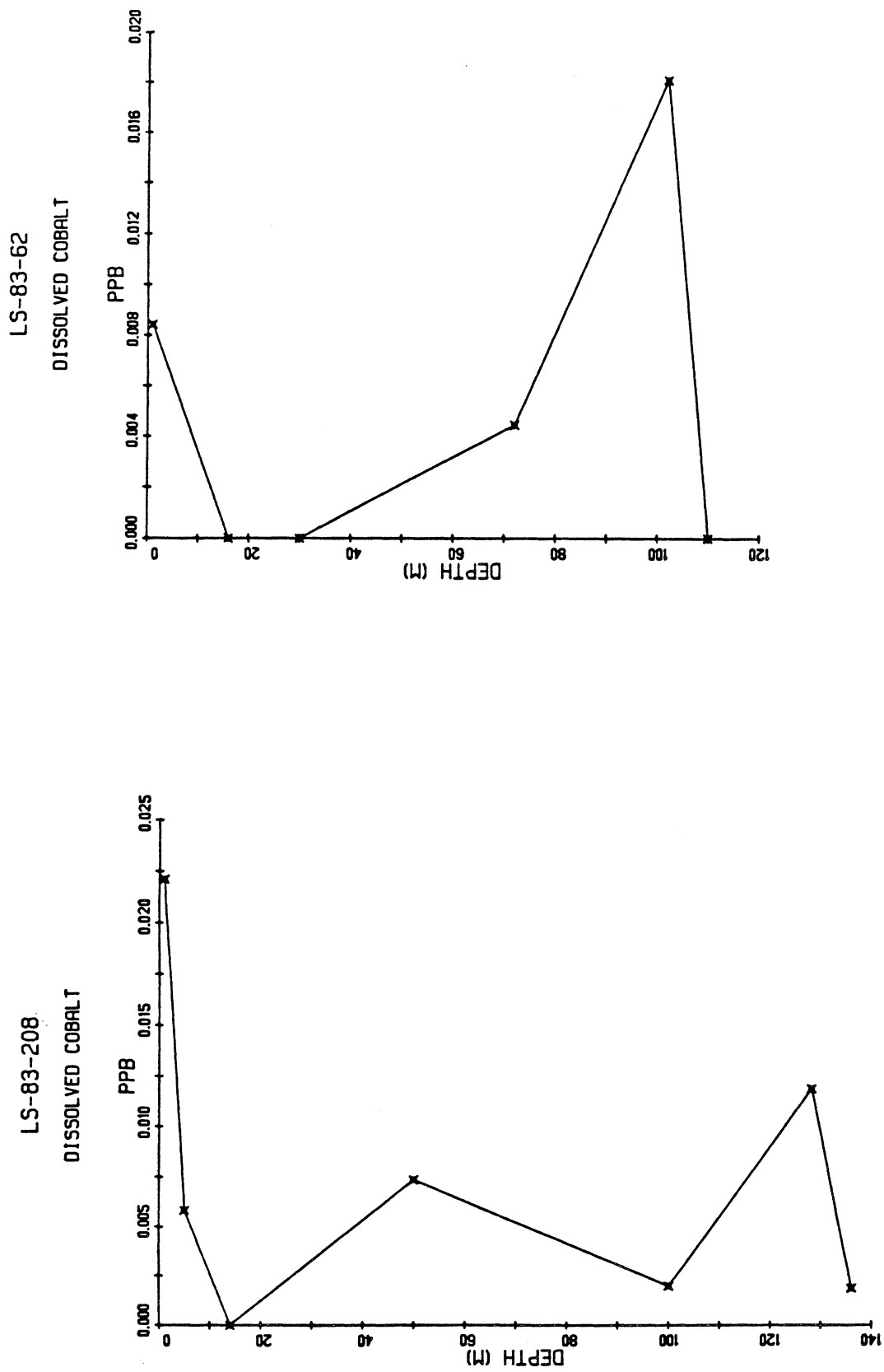


Figure 9. Vertical variation of dissolved cobalt in 1983 Lake Superior water.

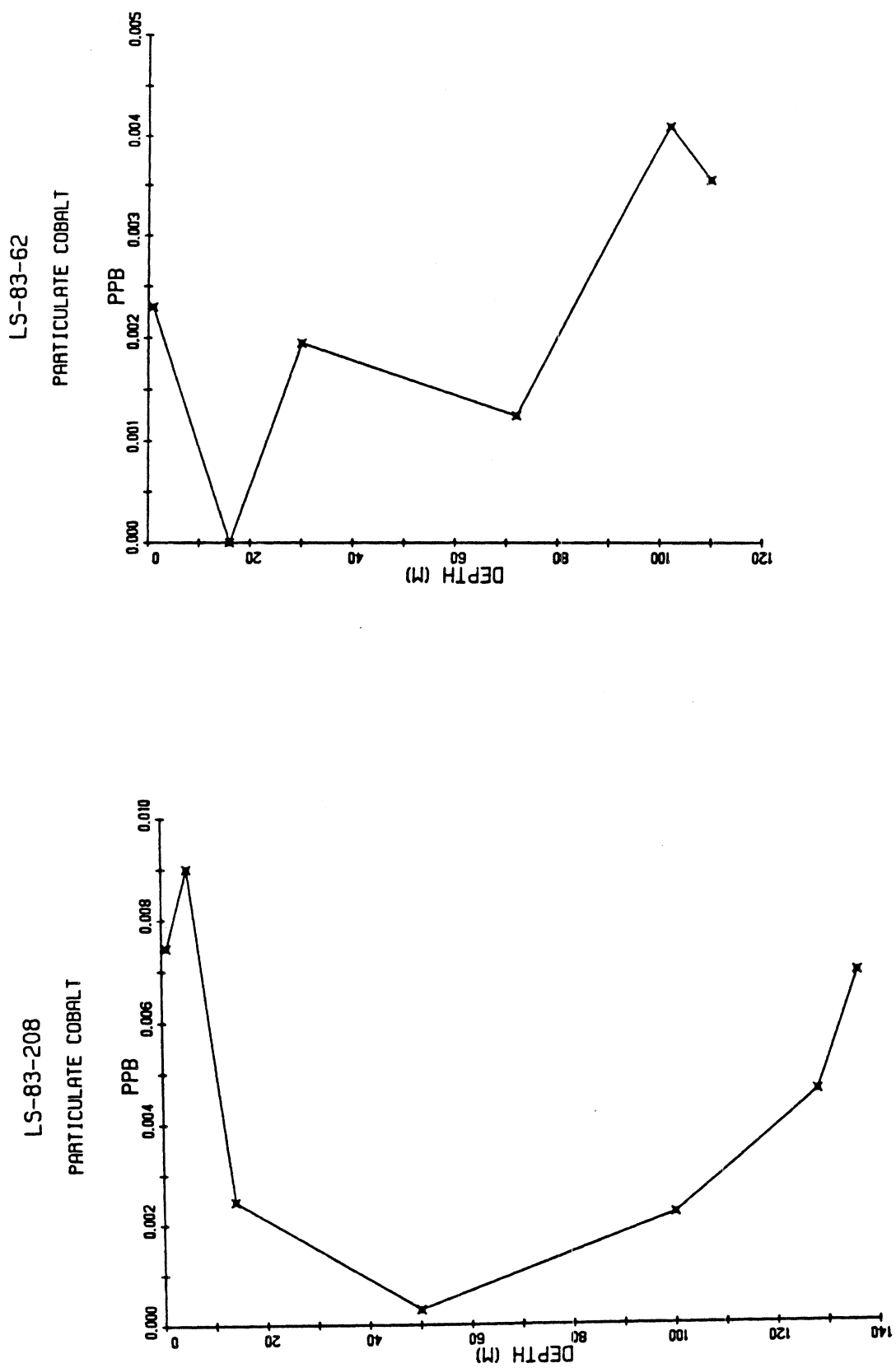


Figure 10. Vertical variation of particulate cobalt in 1983 Lake Superior water.

Dissolved and Particulate Chromium

At both stations, hypolimnetic concentrations of dissolved cobalt were greater than those for the epilimnion (Fig. 11). The concentration peaks at both stations are believed due to sample contamination at the time of collection.

For particulate chromium, concentrations were elevated near the surface and near the bottom relative to mid-water depths (Fig. 12). Some of the observed variation may be due to sample contamination at the time of collection. The elevated concentrations in the epilimnion at station LS-83-208 are more likely due to erosion of the nearby shoreline.

Dissolved and Particulate Copper

Both dissolved and particulate copper varied inconsistently with depth at the two stations (Figs. 13 and 14). Elevated epilimnetic particulate copper concentrations at LS-83-208 are most likely due to erosion of the nearby shoreline.

Dissolved and Particulate Iron

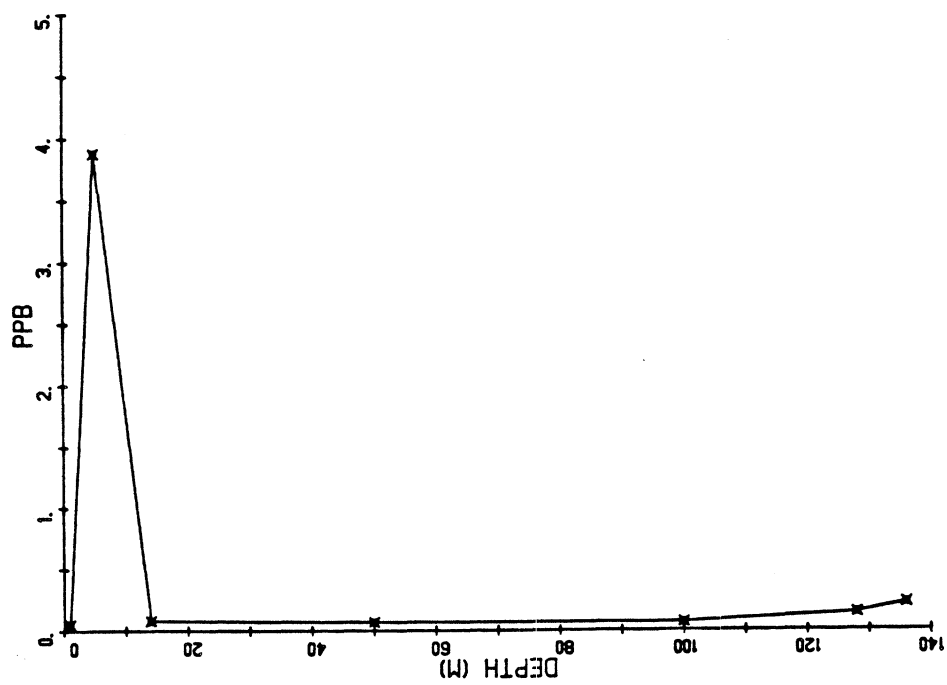
At both locations, both particulate and dissolved iron concentrations were elevated near the bottom (Figs. 15 and 16). This is believed to be because of sediment resuspension or the occurrence of a nephroid layer. Both dissolved and particulate concentrations of iron are elevated in the epilimnion at LS-83-208. This is believed due to the erosion of the nearby shoreline.

Dissolved Lithium

Dissolved lithium concentrations displayed no significant change in concentration from the surface to the bottom of the water column (Fig. 17).

LS-83-208

DISSOLVED CHROMIUM



LS-83-62

DISSOLVED CHROMIUM

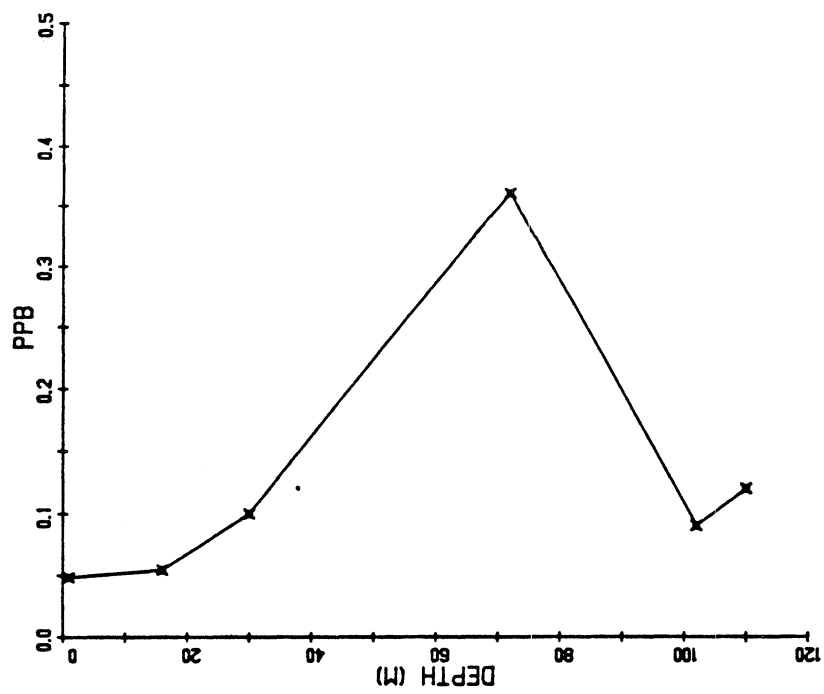


Figure 11. Vertical variation of dissolved chromium in 1983 Lake Superior water.

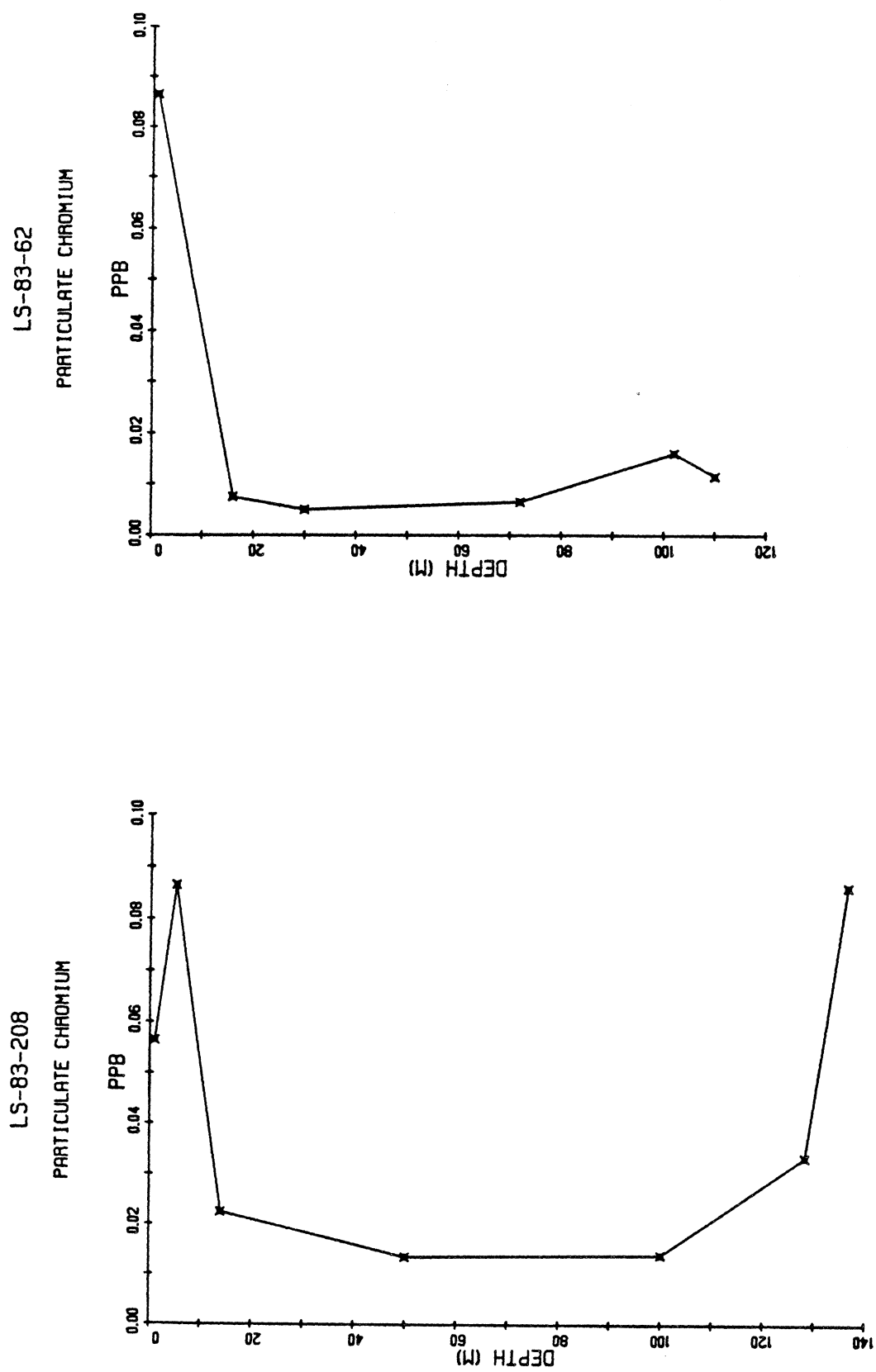


Figure 12. Vertical variation of particulate chromium in 1983 Lake Superior water.

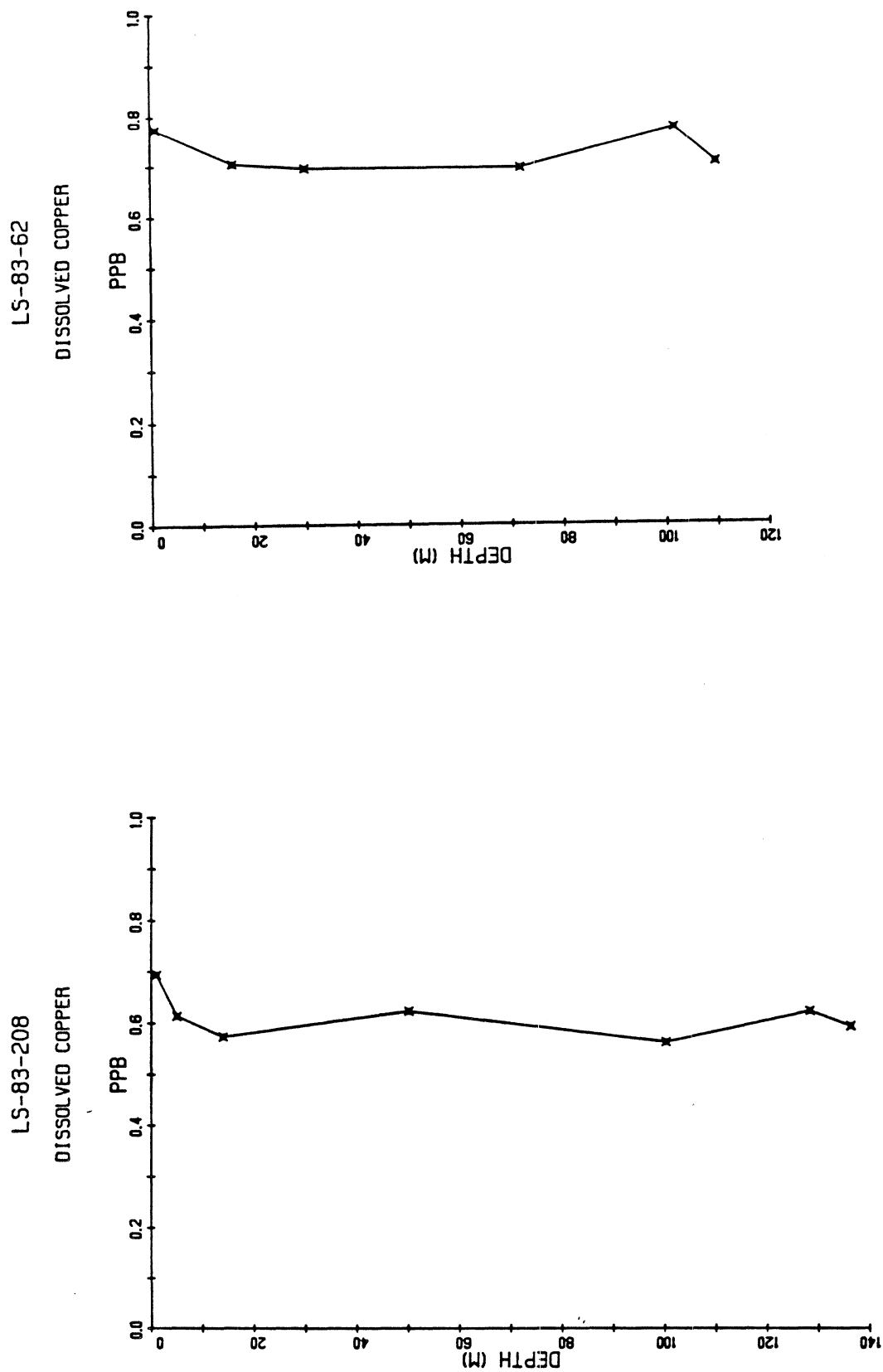
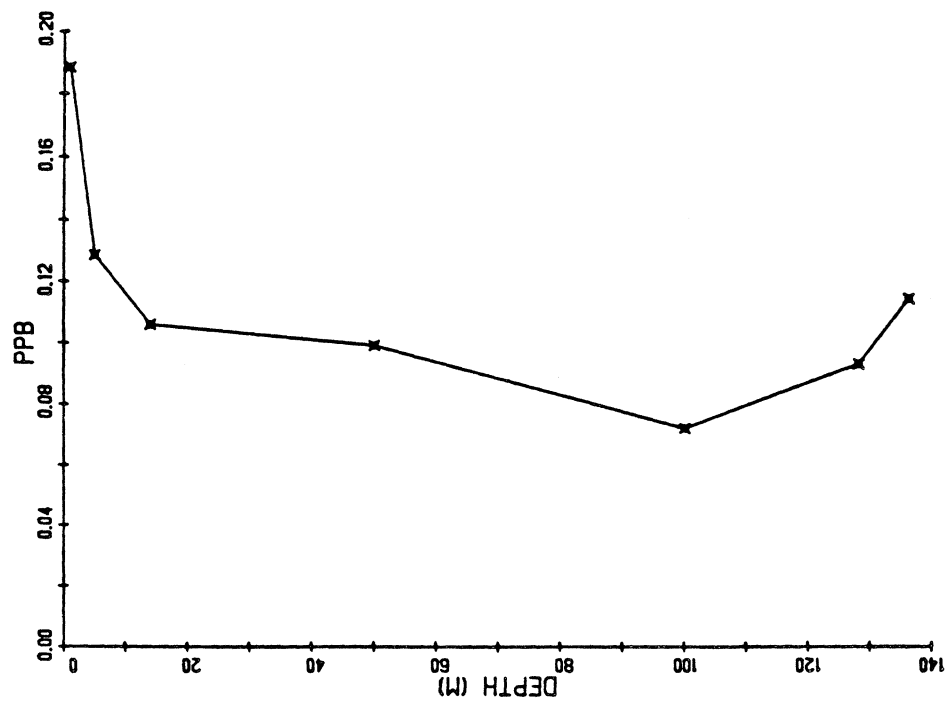


Figure 13. Vertical variation of dissolved copper in 1983 Lake Superior water.

LS-83-208

PARTICULATE COPPER



LS-83-62

PARTICULATE COPPER

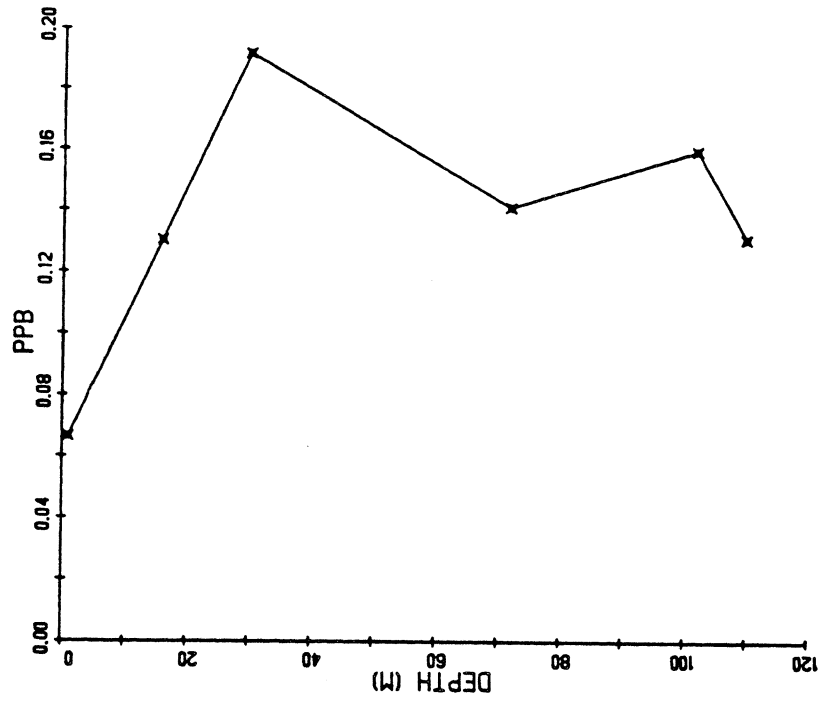


Figure 14. Vertical variation of particulate copper in 1983 Lake Superior water.

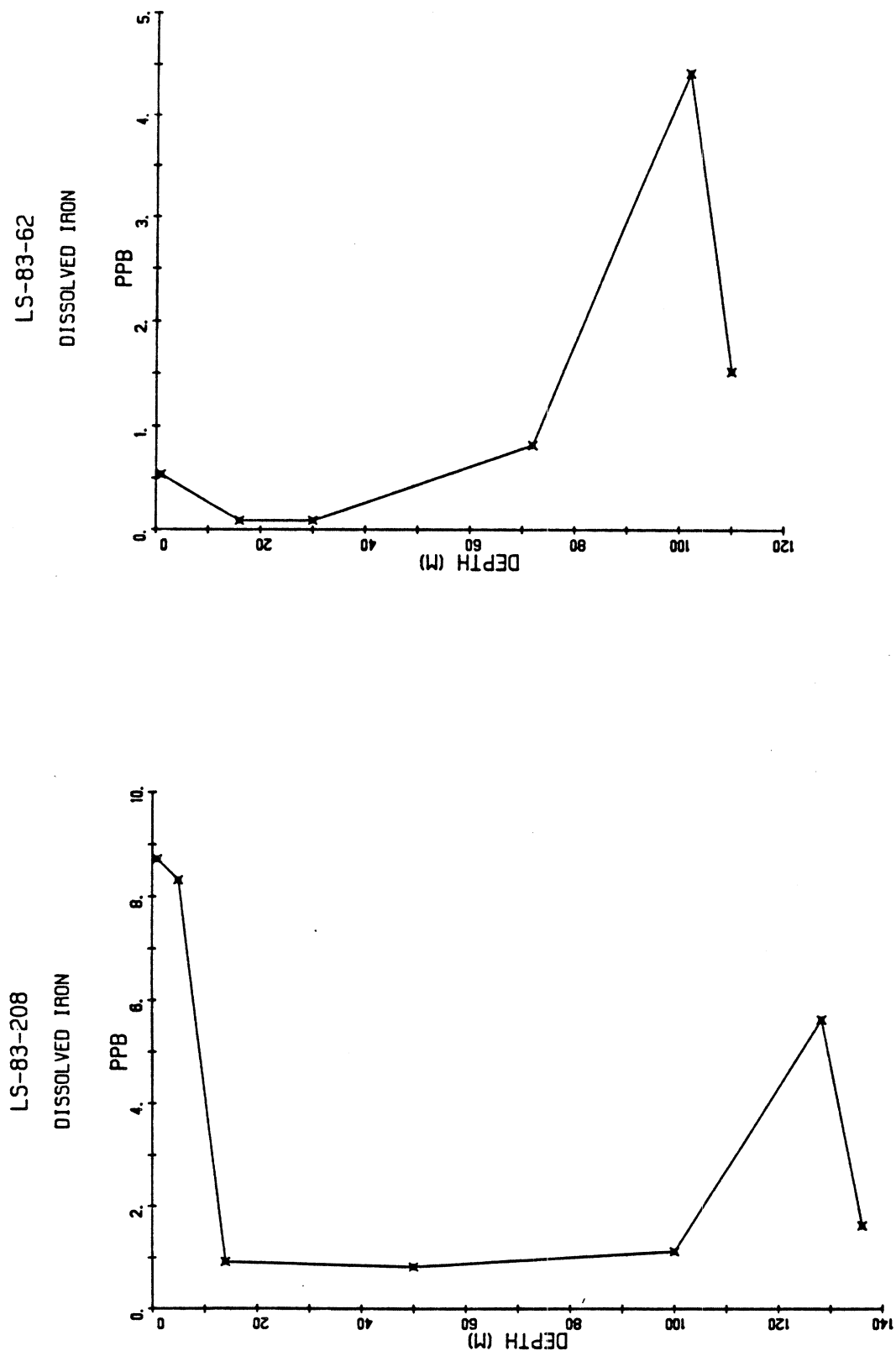
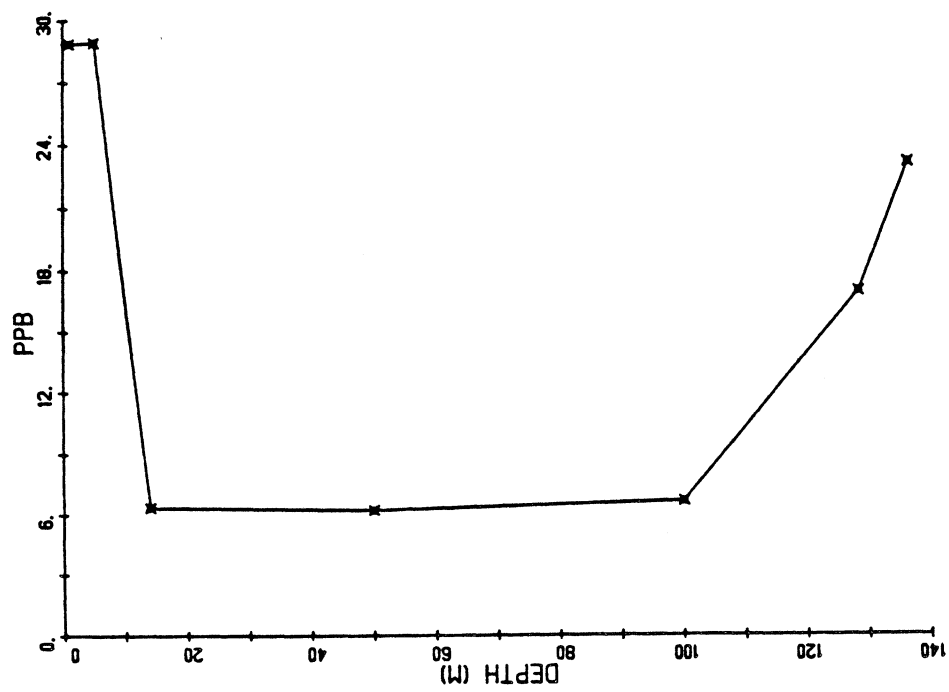


Figure 15. Vertical variation of dissolved iron in 1983 Lake Superior water.

LS-83-208

PARTICULATE IRON



LS-83-62

PARTICULATE IRON

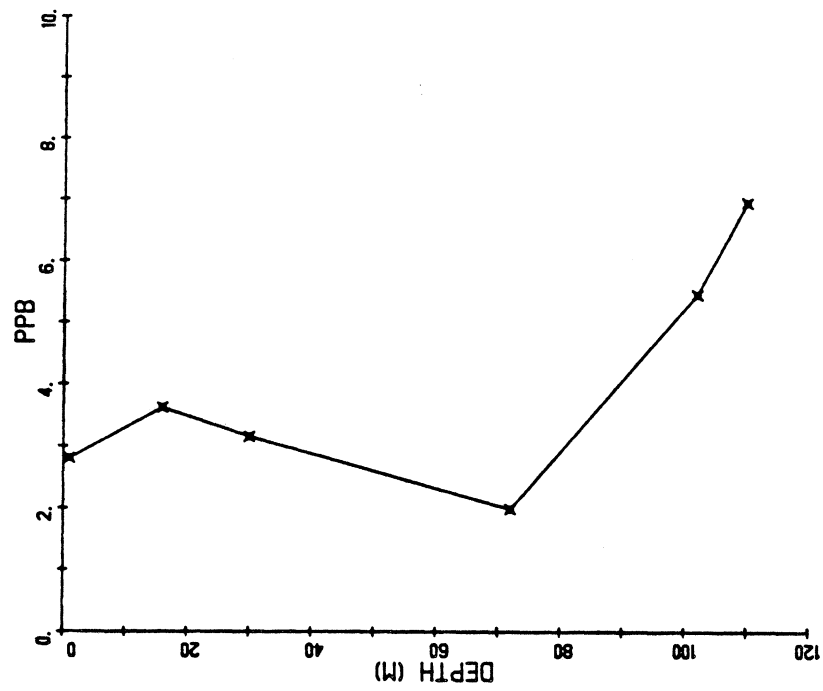


Figure 16. Vertical variation of particulate iron in 1983 Lake Superior water.

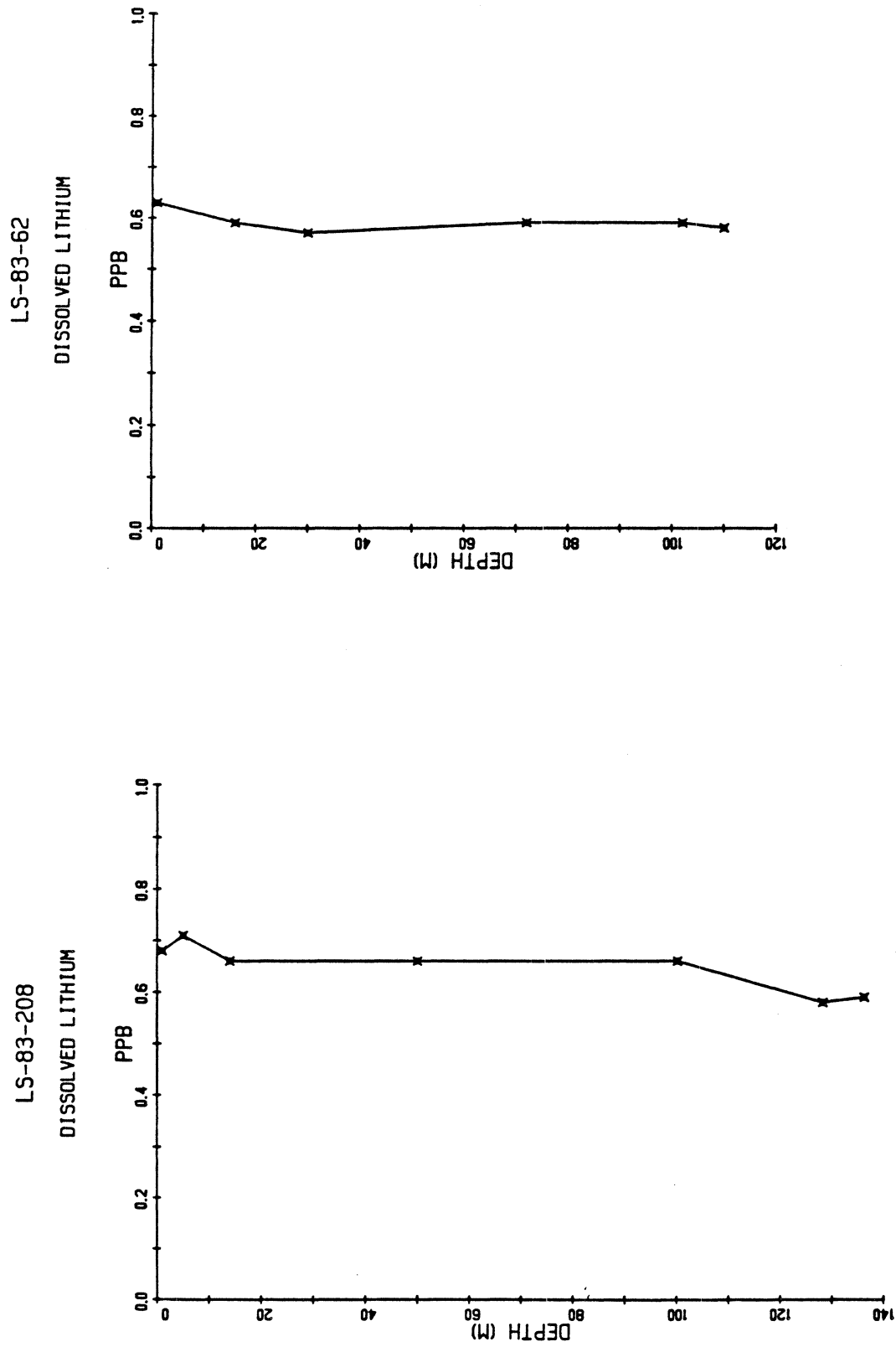


Figure 17. Vertical variation of dissolved lithium in 1983 Lake Superior water.

Dissolved and Particulate Manganese

For dissolved manganese, epilimnetic concentrations were consistently higher than those in the hypolimnion (Fig. 18). For particulate manganese, concentrations in the epilimnion and near the bottom were higher than those at mid-water depths (Fig. 19). The elevation of both dissolved and particulate concentrations at station LS-83-208 is most likely due to erosion of the nearby bluffs.

Dissolved and Particulate Molybdenum

Both dissolved and particulate molybdenum concentrations were higher in the epilimnion than in the hypolimnion (Figs. 20 and 21). For the particulate molybdenum, the differences could be due to sample contamination at the time of collection. For station LS-83-208, erosion of the nearby bluffs may have contributed to elevated epilimnetic concentrations.

Dissolved and Particulate Nickel

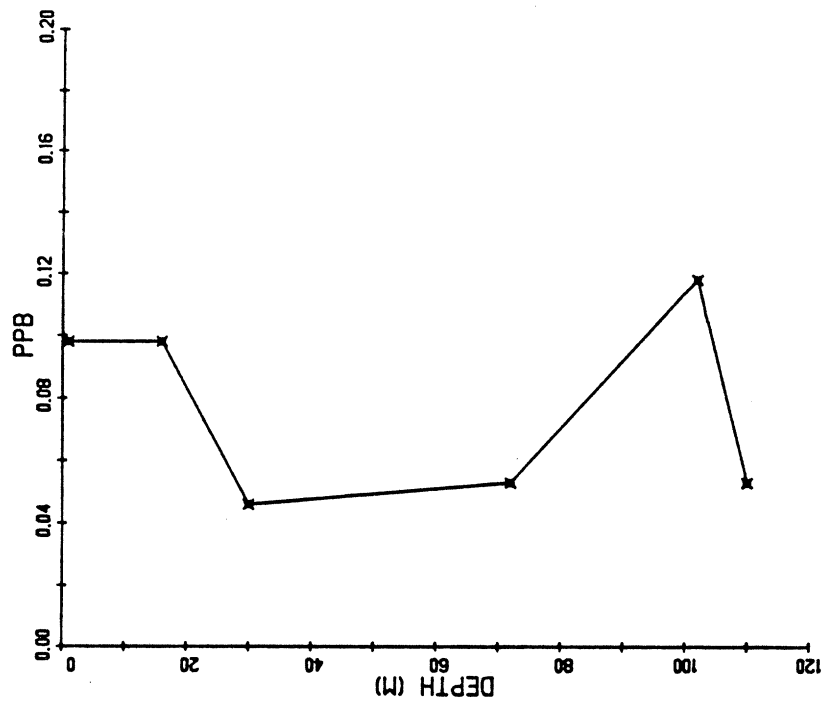
For both dissolved and particulate nickel, surface concentrations were higher than those deeper in the water column (Figs. 22 and 23). This variation may be related to contamination of samples during collection. At station LS-83-208, erosion of the nearby shoreline may have contributed to the elevated surface concentrations.

Particulate Lead

At both locations, particulate lead concentrations were highest in surface waters (Fig. 24). This is believed to be due to contamination of the samples at the time of collection.

LS-83-62

DISSOLVED MANGANESE



LS-83-208

DISSOLVED MANGANESE

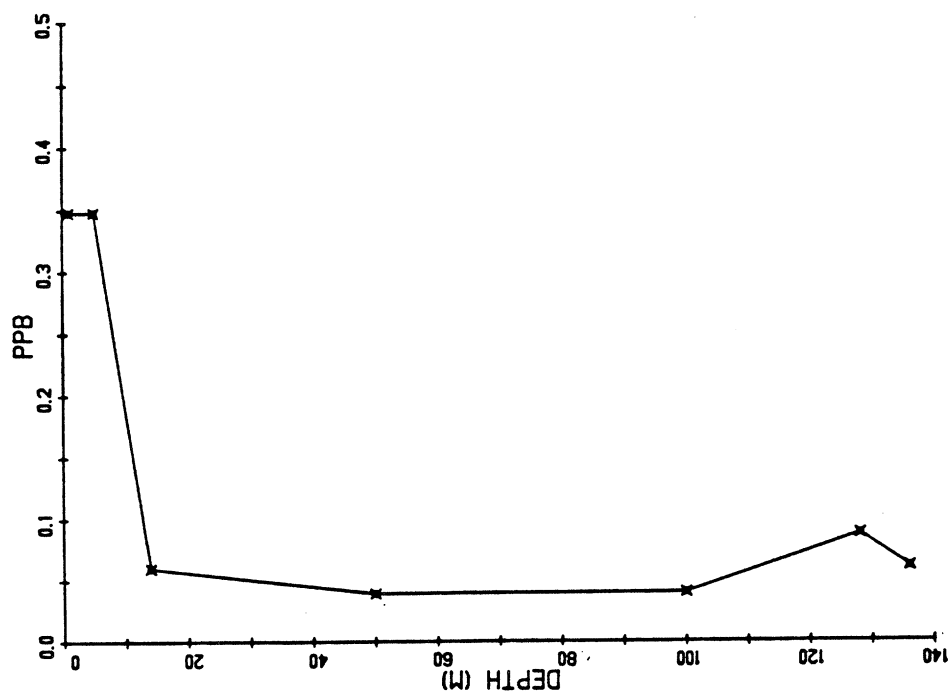
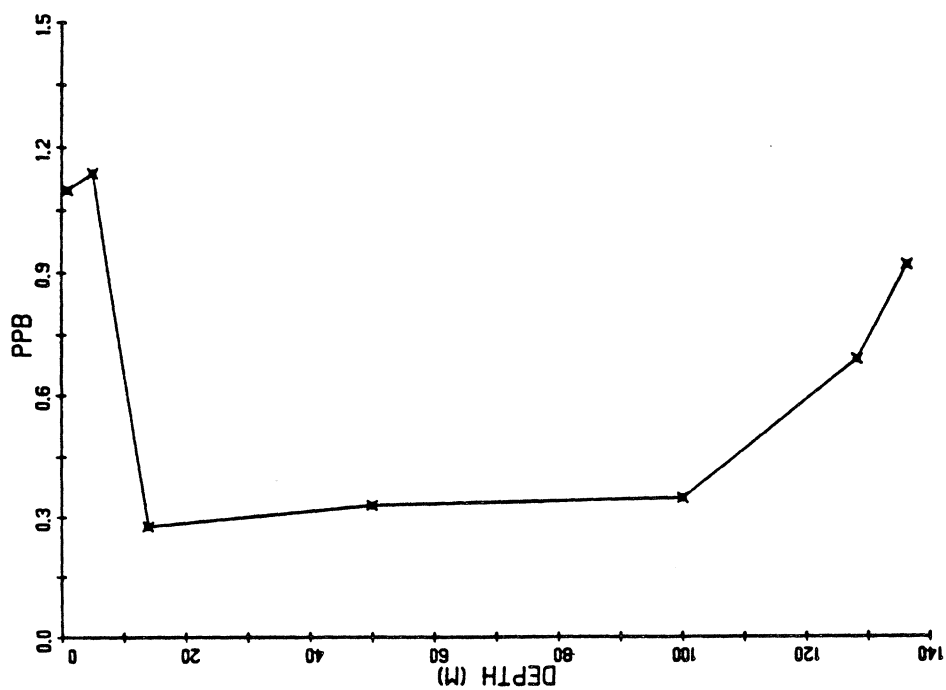


Figure 18. Vertical variation of dissolved manganese in 1983 Lake Superior water.

LS-83-208

PARTICULATE MANGANESE



LS-83-62

PARTICULATE MANGANESE

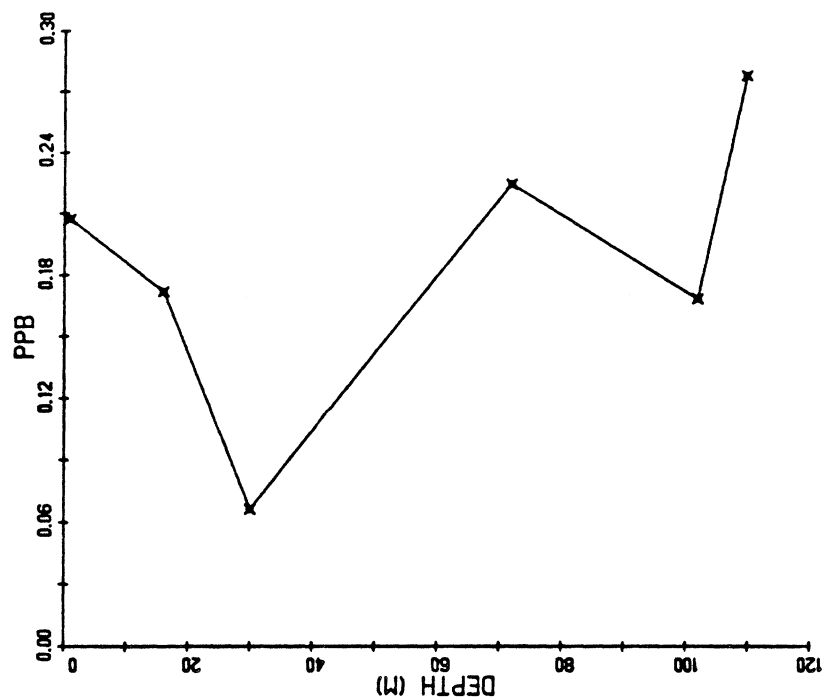


Figure 19. Vertical variation of particulate manganese in 1983 Lake Superior water.

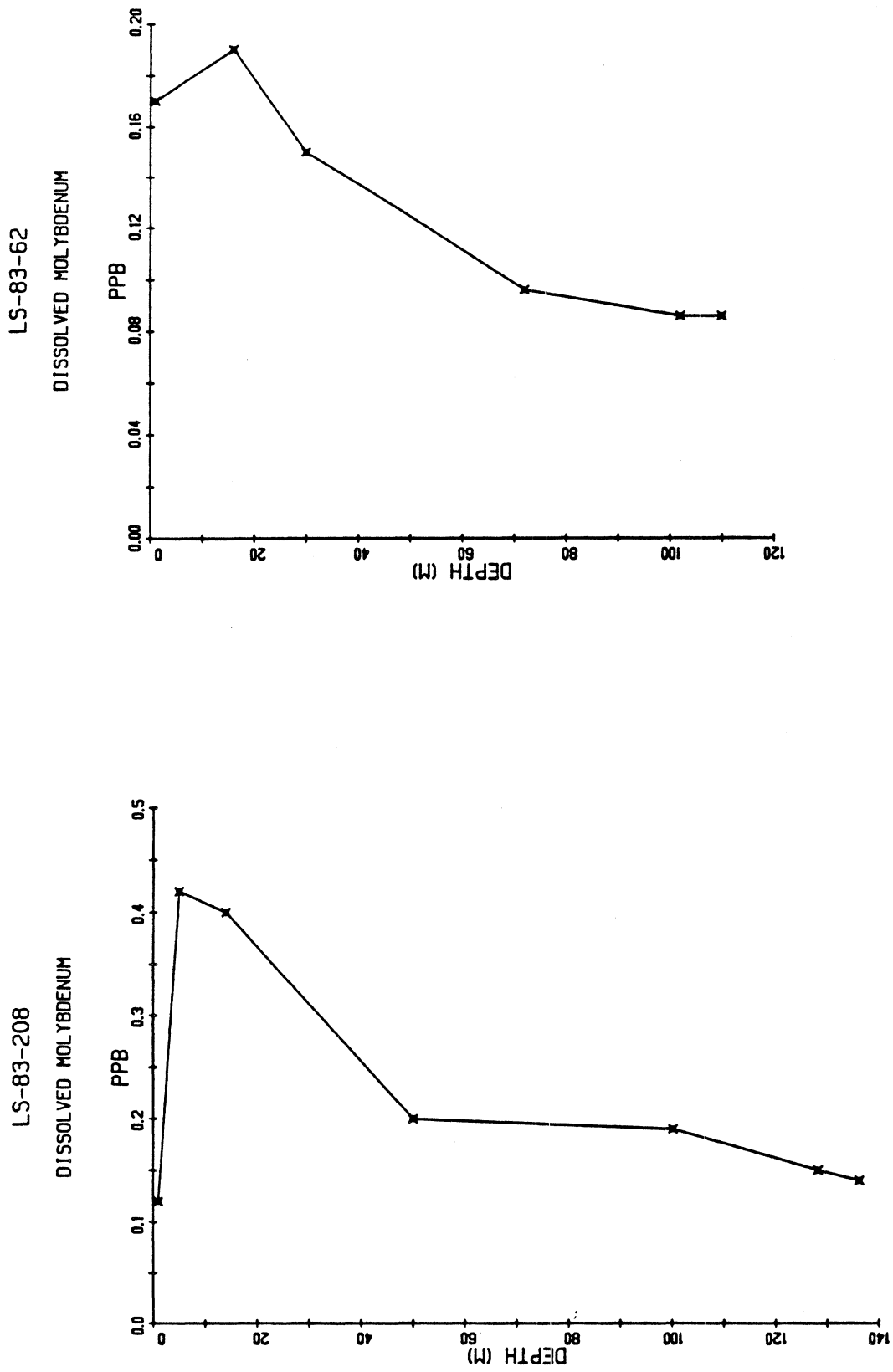


Figure 20. Vertical variation of dissolved molybdenum in 1983 Lake Superior water.

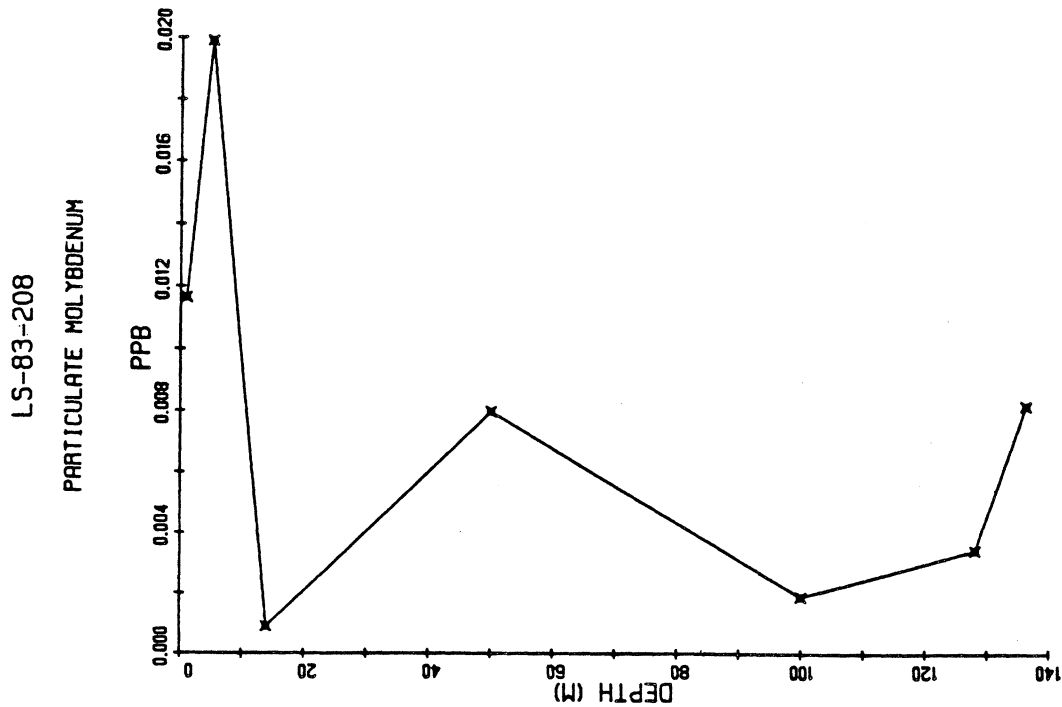
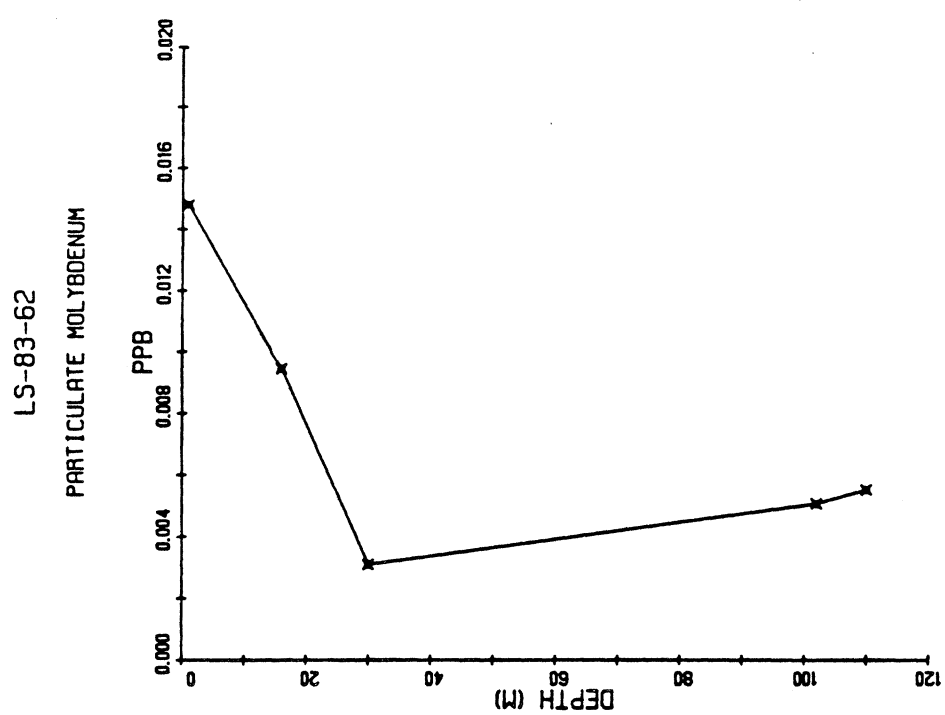


Figure 21. Vertical variation of particulate molybdenum in 1983 Lake Superior water.

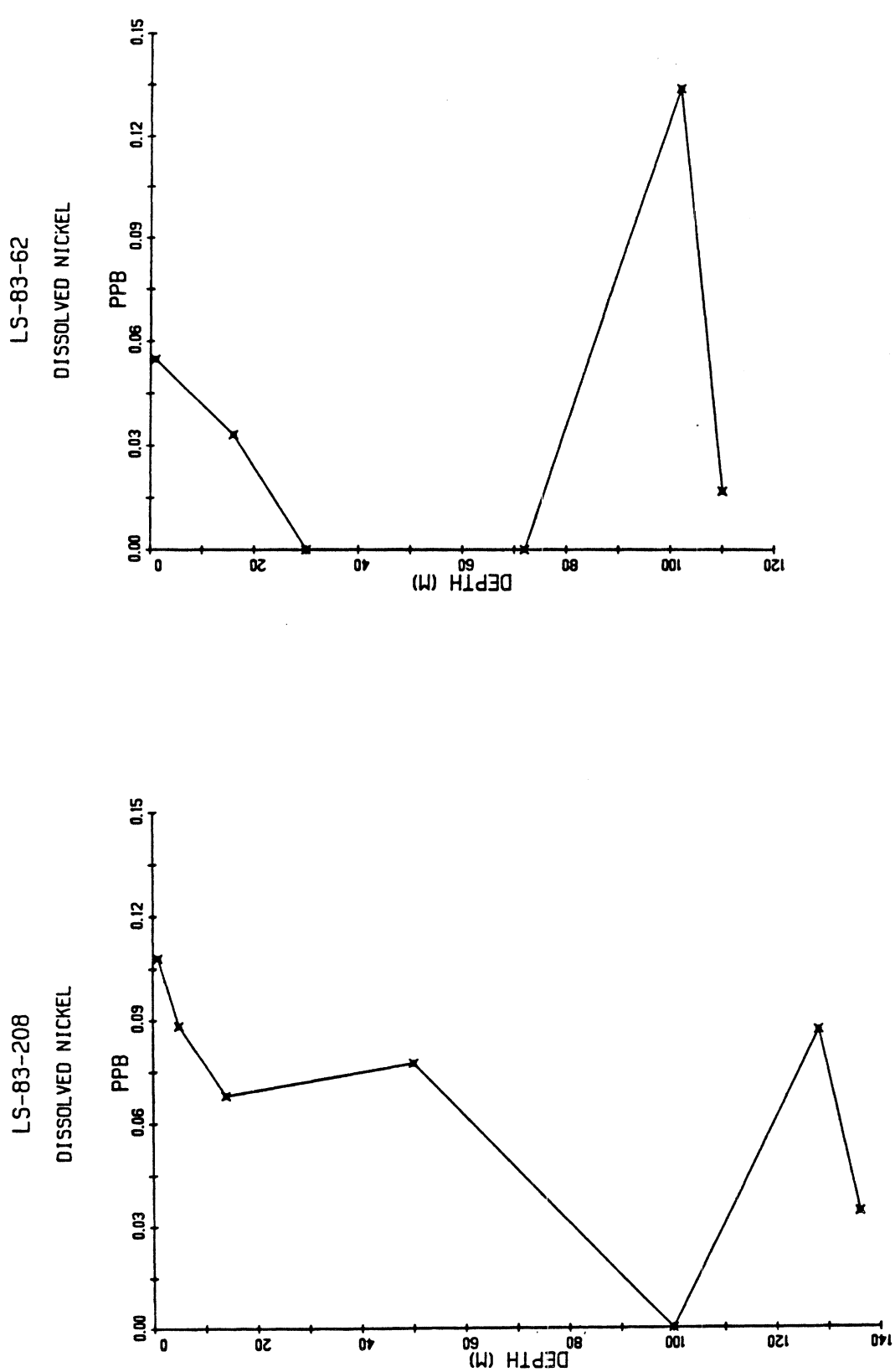
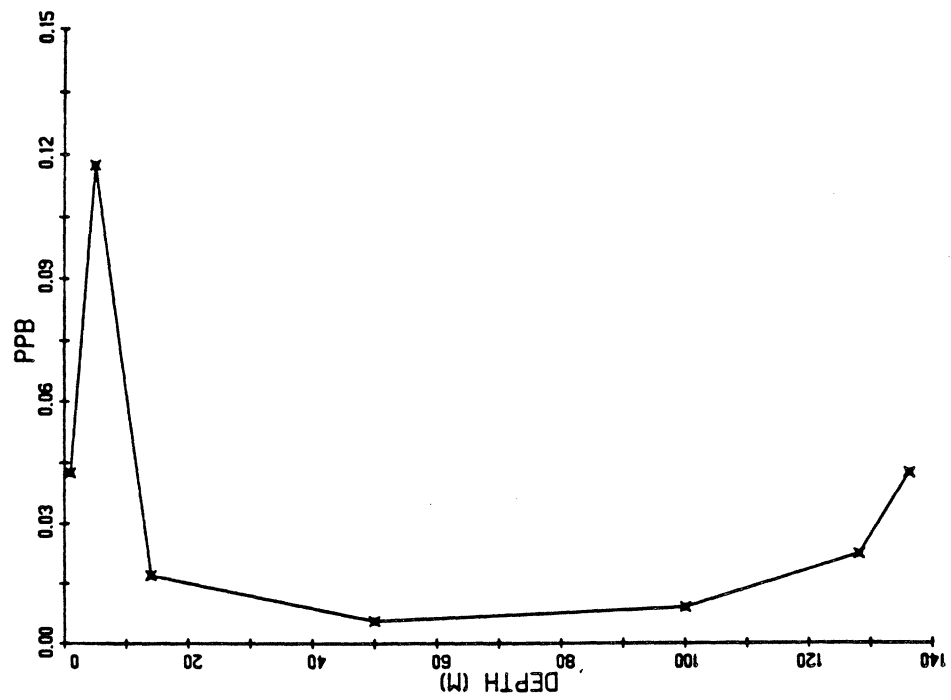


Figure 22. Vertical variation of dissolved nickel in 1983 Lake Superior water.

LS-83-208

PARTICULATE NICKEL



LS-83-62

PARTICULATE NICKEL

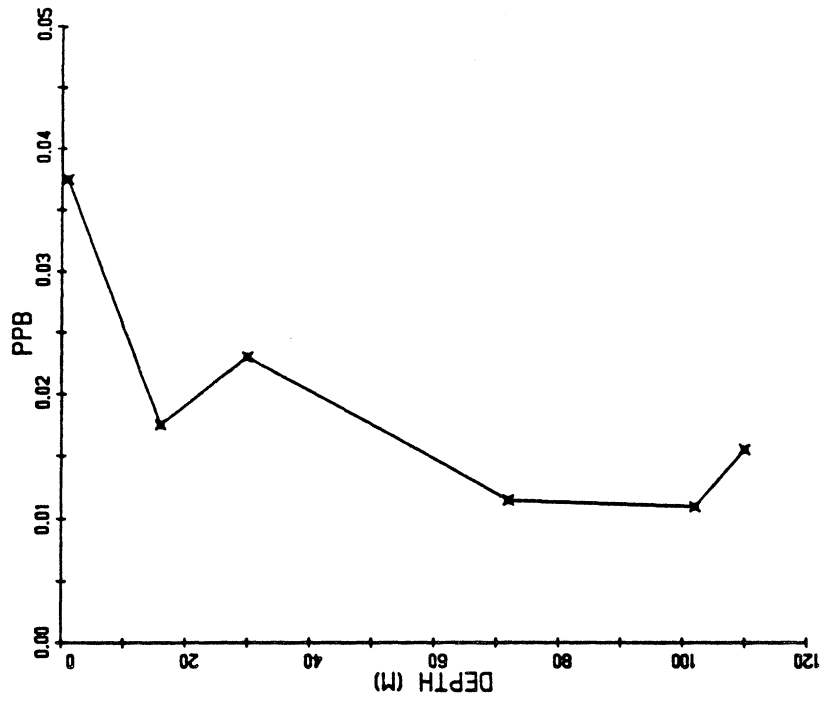


Figure 23. Vertical variation of particulate nickel in 1983 Lake Superior water.

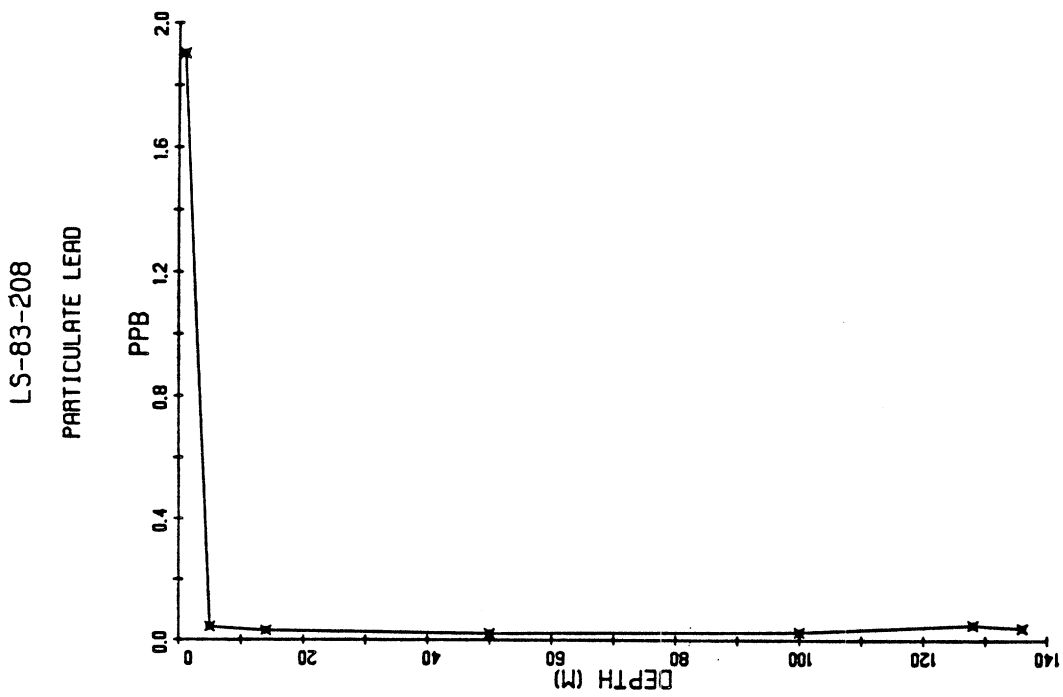
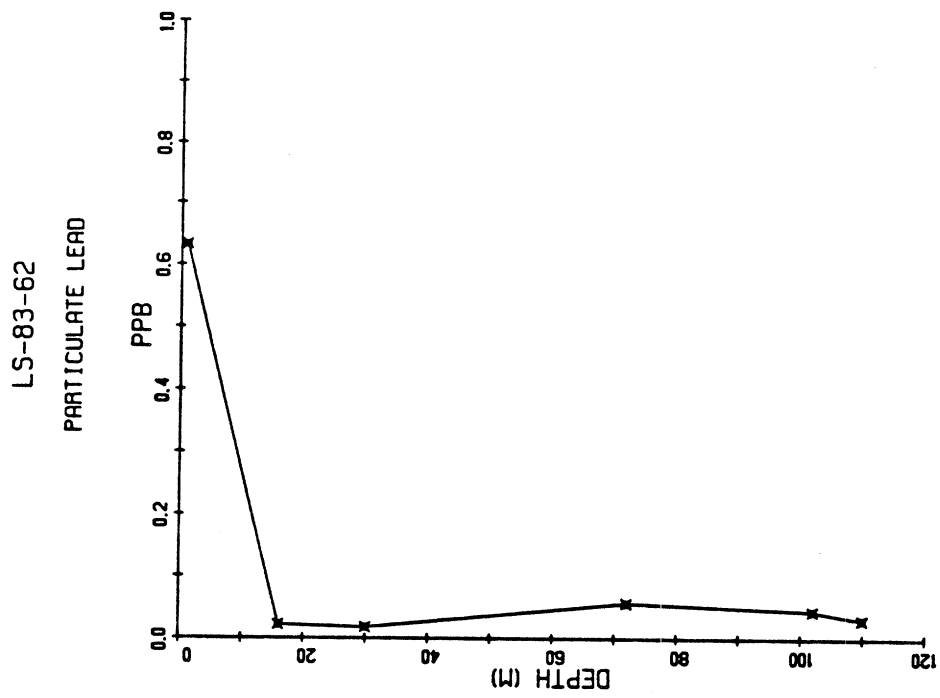


Figure 24. Vertical variation of particulate lead in 1983 Lake Superior water.

Dissolved Antimony

There was no consistent variation of dissolved antimony with depth at the two locations (Fig. 25). At station LS-83-208, concentrations in the epilimnion and thermocline were relatively high compared to other depths. The erosion of the nearby bluffs may have been responsible for this vertical variation.

Dissolved Selenium

At both locations, concentrations of dissolved selenium in the 1-m sample were very low (Fig. 26). At station LS-83-62, selenium concentration peaked in the thermocline.

Dissolved Strontium

There was no consistent variation in dissolved strontium concentrations with depth for the two stations (Fig. 27). At station LS-83-208, the strontium concentration was elevated near the bottom.

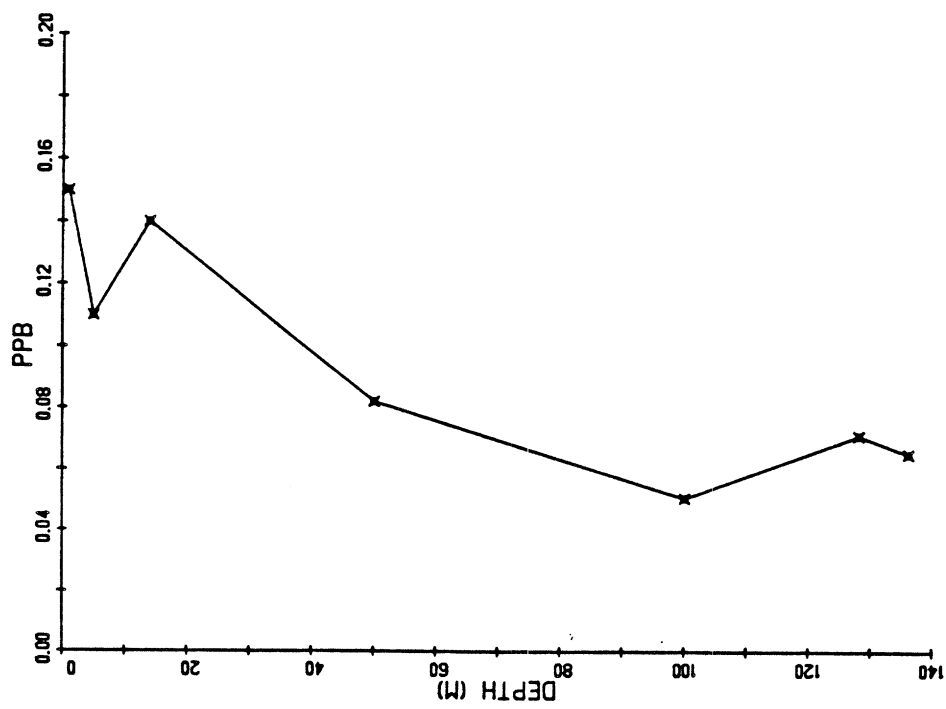
Dissolved and Particulate Vanadium

Dissolved vanadium did not consistently vary with depth at the two locations (Fig. 28). At station LS-83-208, its concentration was highest in the epilimnion. The erosion of the nearby clay bluffs probably contributed to this high concentration.

At both stations, particulate vanadium concentrations were elevated at the surface and bottom relative to mid-water depths (Fig. 29). The high concentration in the epilimnion at station LS-83-208 was most likely due to erosion of the nearby shoreline.

LS-83-208

DISSOLVED ANTIMONY



LS-83-62

DISSOLVED ANTIMONY

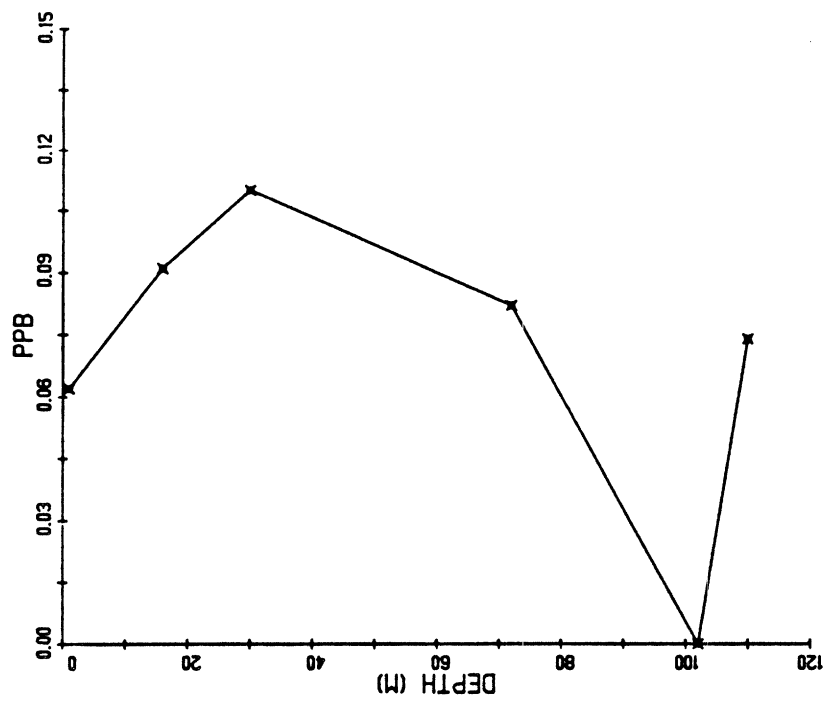


Figure 25. Vertical variation of dissolved antimony in 1983 Lake Superior water.

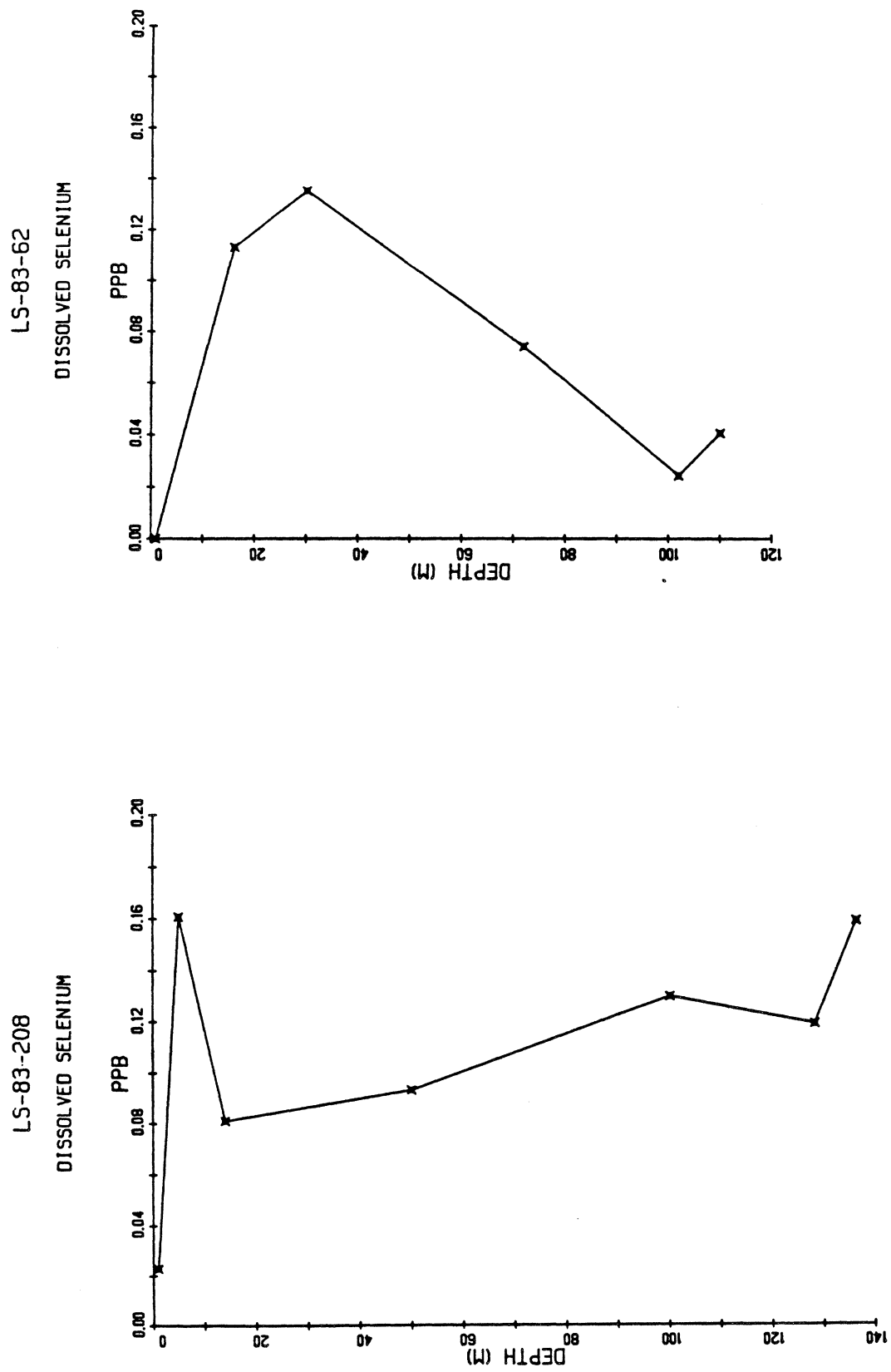


Figure 26. Vertical variation of dissolved selenium in 1983 Lake Superior water.

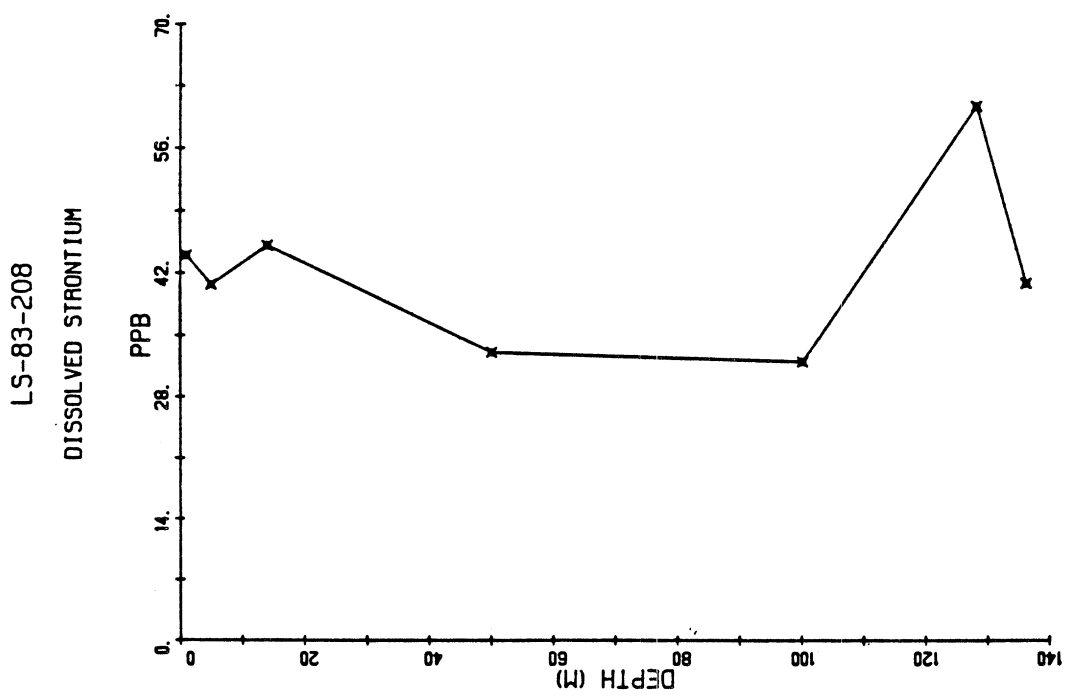
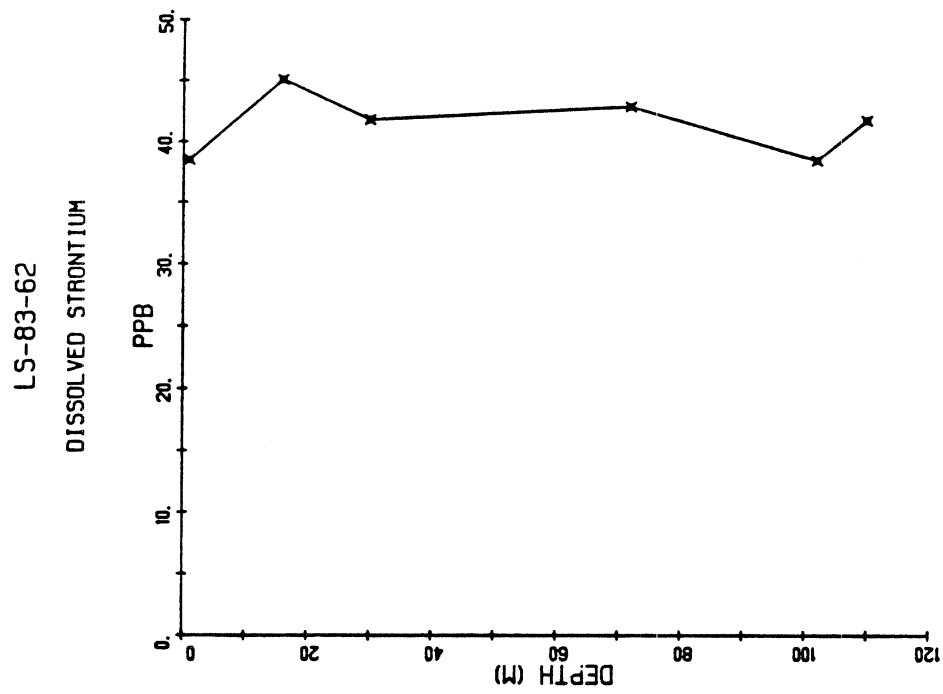


Figure 27. Vertical variation of dissolved strontium in 1983 Lake Superior water.

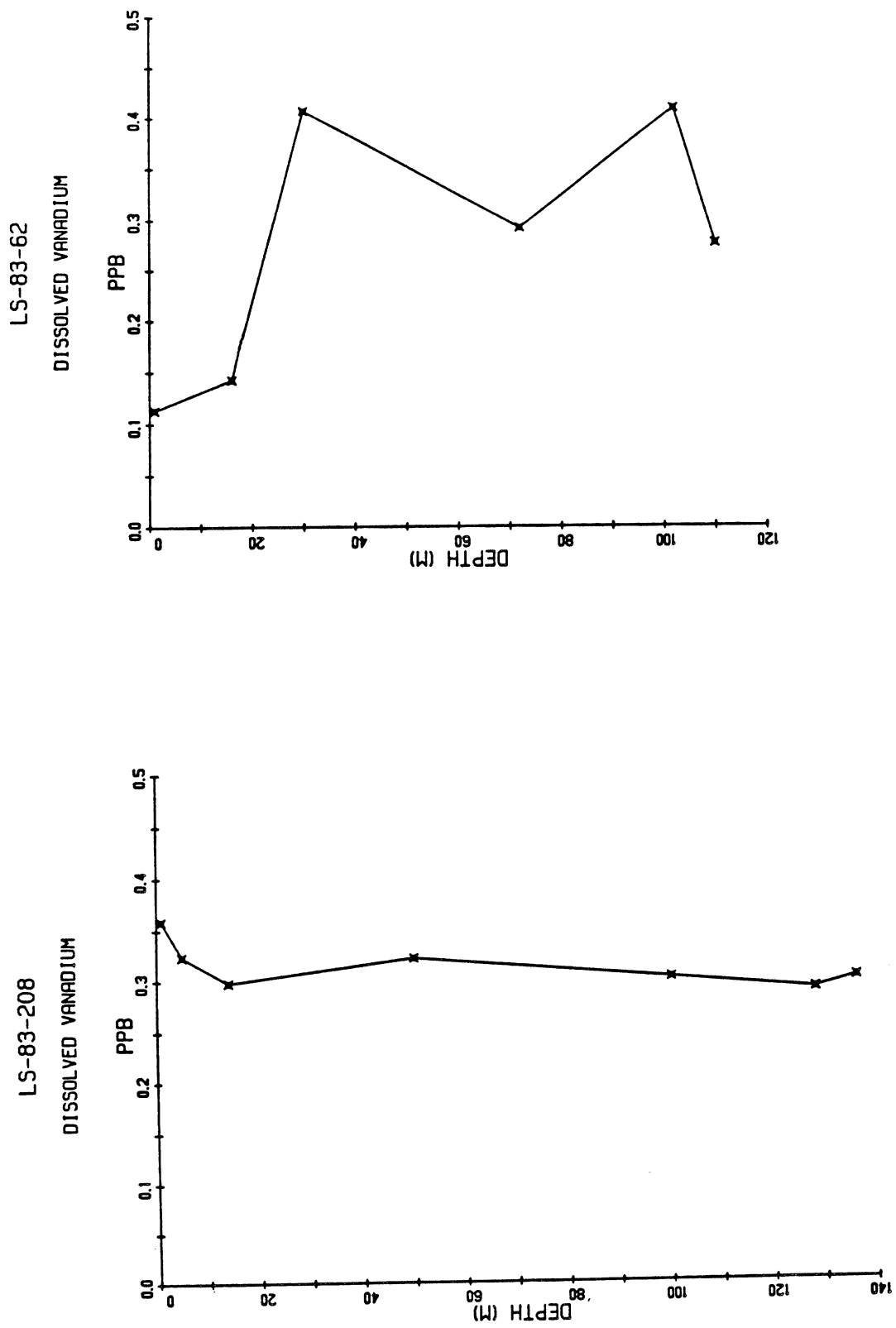


Figure 28. Vertical variation of dissolved vanadium in 1983 Lake Superior water.

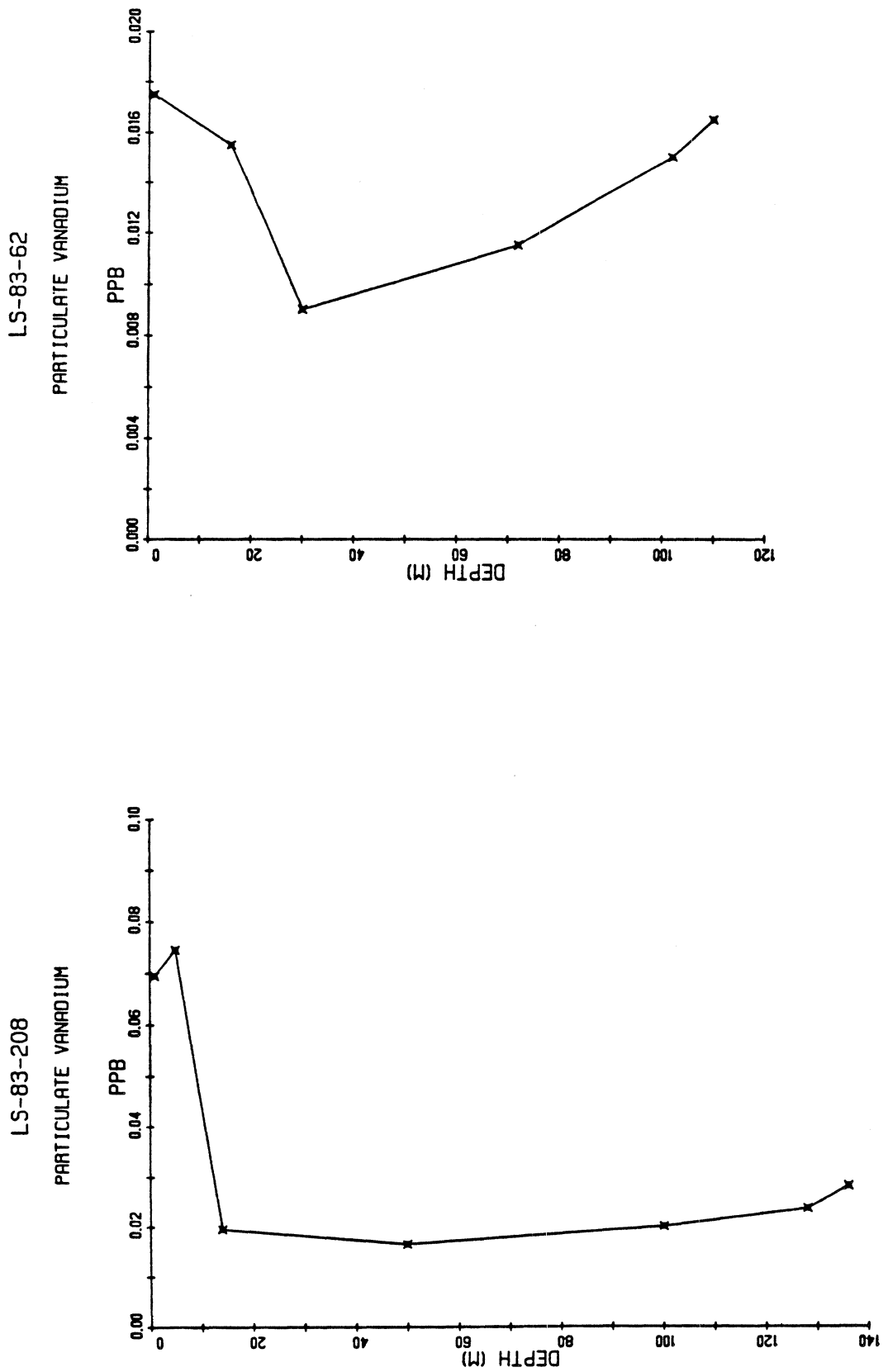


Figure 29. Vertical variation of particulate vanadium in 1983 Lake Superior water.

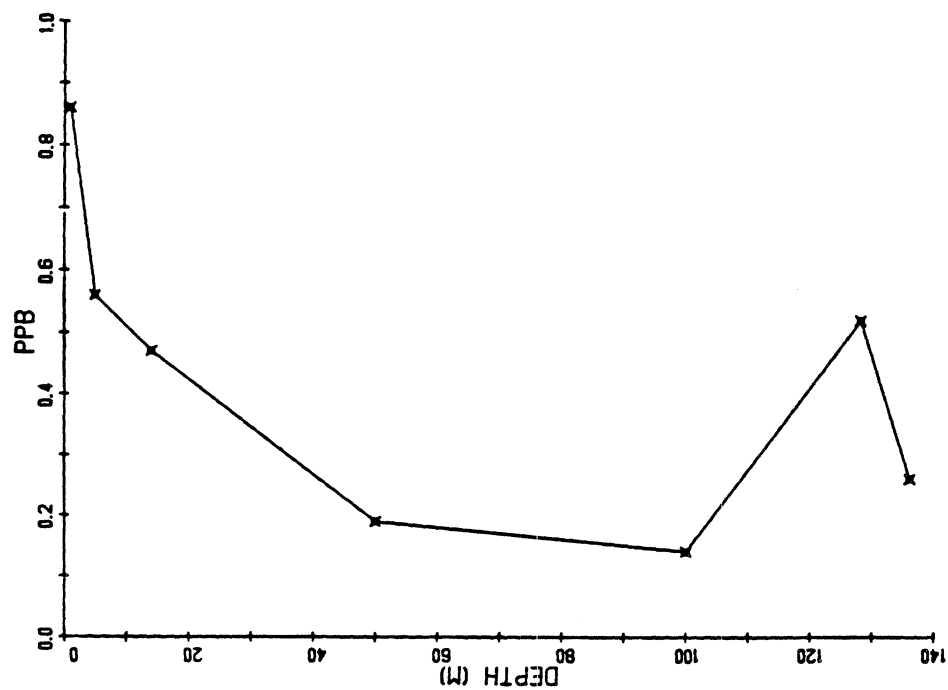
Dissolved and Particulate Zinc

Dissolved zinc concentrations were highest at the surface at both stations (Fig. 30). Particulate zinc concentrations displayed no significantly consistent variation at the two sites (Fig. 31). At LS-83-208, its concentration was highest at the surface, perhaps reflecting erosion of the nearby shoreline.

PARTITIONING OF METALS BETWEEN DISSOLVED AND PARTICULATE FRACTIONS

The partitioning of metals between the particulate and dissolved fractions in water is important to understanding the dynamics of metals in the Great Lakes. By definition, the dissolved fraction is all that passed through a 0.5 μ m pore size filter, and the particulate fraction is that retained on the filter. For those metals for which the percent in each fraction could be calculated or estimated, aluminum, cadmium, iron, mercury, manganese, and lead were primarily associated with the particulate fraction (Table 81). Significant fractions of the total nickel and selenium were associated with the particulate fraction, and a minor fraction of the copper was associated with the particulate fraction. Those metals whose major fraction is associated with particulate matter tend to be extremely variable in concentration throughout the lake or in vertical profile due to their apparent heterogeneous distribution in the water column.

LS-83-208
DISSOLVED ZINC



LS-83-62
DISSOLVED ZINC

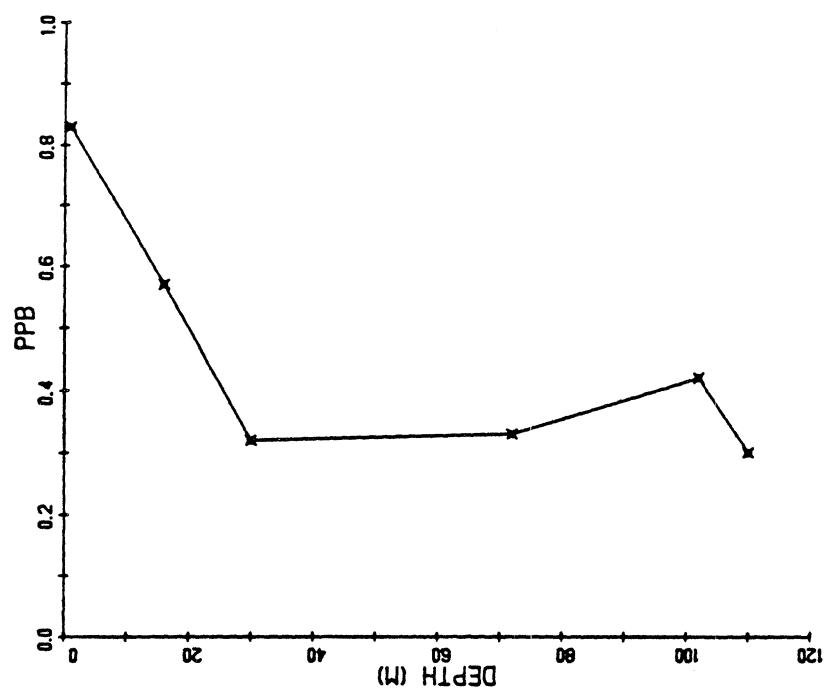
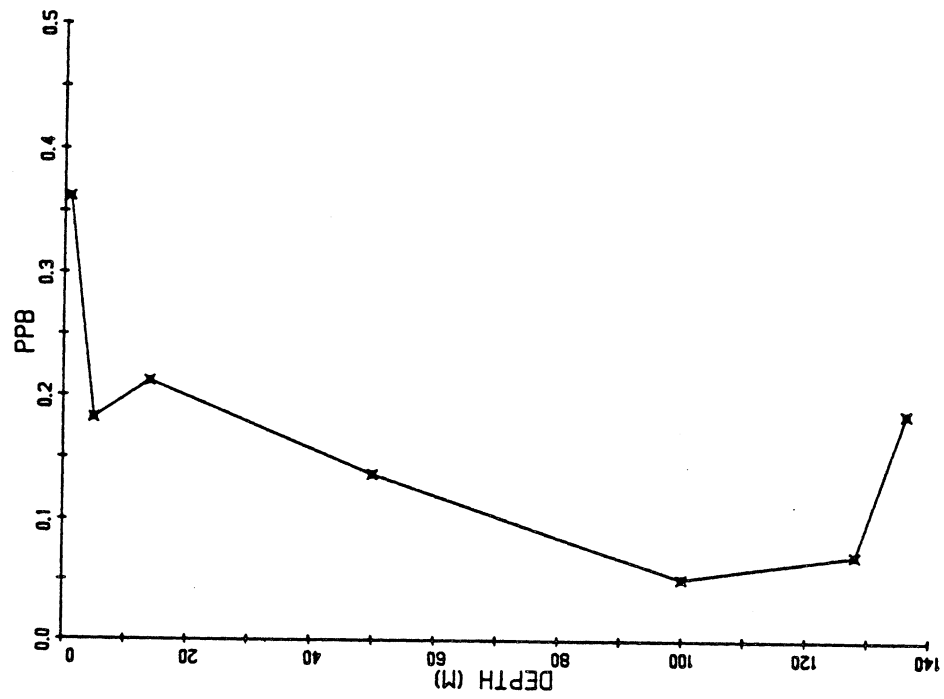


Figure 30. Vertical variation of dissolved zinc in 1983 Lake Superior water.

LS-83-208

PARTICULATE ZINC



LS-83-62

PARTICULATE ZINC

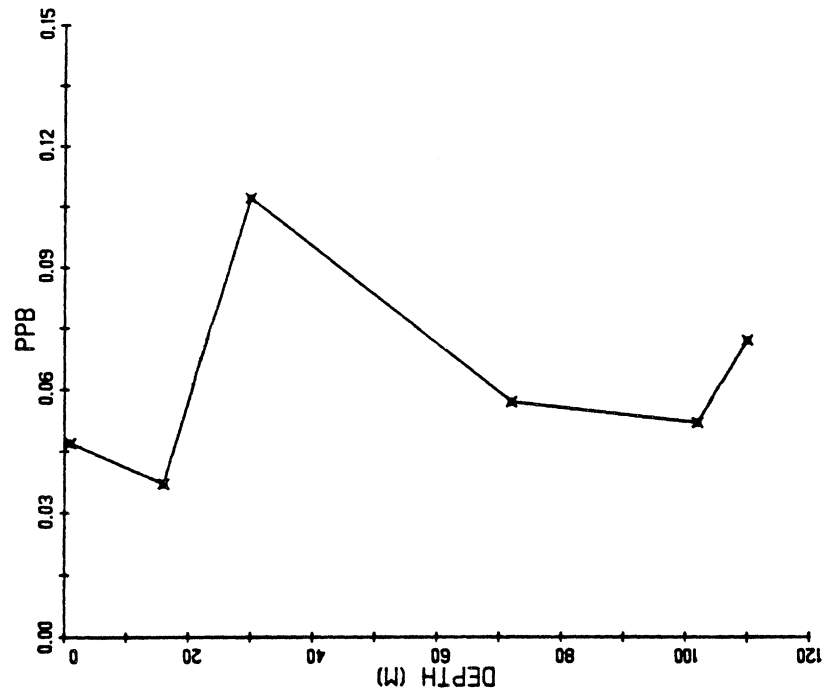


Figure 31. Vertical variation of particulate zinc in 1983 Lake Superior water.

Table 81. Partitioning of metals between the dissolved and particulate fractions in Lake Superior epilimnetic waters during 1983.

Metal	Percent Dissolved	Percent Particulate
Al	32	68
As	98	2
Ba	100	0
Cd	22	78
Co	100	0
Cr	92	8
Cu	86	14
Fe	24	76
Hg	0	100
Li	100	0
Mn	41	59
Mo	96	4
Ni	70	30
Pb	21	79
Sb	100	0
Se	60	40
Sn	100	0
Sr	100	0
V	98	2
Zn	92	8

TRENDS

Water

For the 1983 and historical data reported here, only the total iron, total manganese, total arsenic, total mercury, dissolved chromium, dissolved copper, dissolved molybdenum, dissolved iron, dissolved manganese, and dissolved strontium data sets were suitable for seeking trends. At the 0.05 level of significance, several possible trends were found (Table 82). These trends should all be considered as tentative because of the generally poor quality of historical data. Though the author attempted to use only those data which seemed of acceptable quality, many uncertainties remained. Median dissolved chromium concentrations exhibited a significant ($P = 0.012$) second-order variation with time. It consistently decreased between 1968 and 1983. Because of the uncertainties involved with these calculated trends, independent confirmation is needed. Unfortunately, these metals are not adequately preserved in sediments to permit confirmation.

Table 82. Time rate of change calculated for a variety of trace metals in Lake Superior water.

Metal	Rate of Change (ppb/yr)	Probability of Significance of the Calculated Change
Mean Total As	-0.028	0.050
Mean Total Fe	-1.4	0.042
Median Total Fe	-0.36	0.080
Median Dissolved Mn	-0.017	0.10
Mean Total Mn	-0.033	0.038
Median Dissolved Sr	0.67	0.0000

Sediments

Vertical profiles of bismuth, calcium, cobalt, chromium, iron, mercury, magnesium, manganese, nickel, lead, zinc, and fraction insoluble in the eastern basin of Lake Superior sediments collected in 1983 are available. Both bismuth and calcium are increasing as sediments become progressively younger (Fig. 32). Past studies have provided data which indicate that components of the sediment with which calcium is associated may be strongly altered by diagenesis (Rossmann 1984b). Thus, the increase in calcium may be related to diagenesis of calcium-rich fractions of the sediment.

Chromium shows no apparent change in concentration, and cobalt exhibits a slight increase in concentration in recent sediments relative to older sediments (Fig. 33). Chromium profiles may be affected by diagenesis (Rossmann 1984b). The impact of diagenesis on cobalt profiles is unknown; however, inputs of cobalt to the lake appear to have increased with time.

Iron shows no apparent change in concentration in recent sediments relative to older sediments; however, mercury concentrations have a subsurface peak (Fig. 34). Work on Great Lakes sediments has led to the conclusion that iron profiles are strongly affected by diagenesis; whereas, mercury profiles are not affected to any substantial degree (Johansen et al. 1983, Rossmann 1984b). For Lake Ontario cores, the mercury peak occurred between 1940 and 1970. Because a large fraction of the mercury is derived from atmospheric inputs, it is expected that the subsurface mercury peak in the Lake Superior core corresponds to a similar time period. Mercury concentrations in recent Lake Superior sediments are less than those in older sediments. Thus, mercury inputs to the lake have recently decreased.

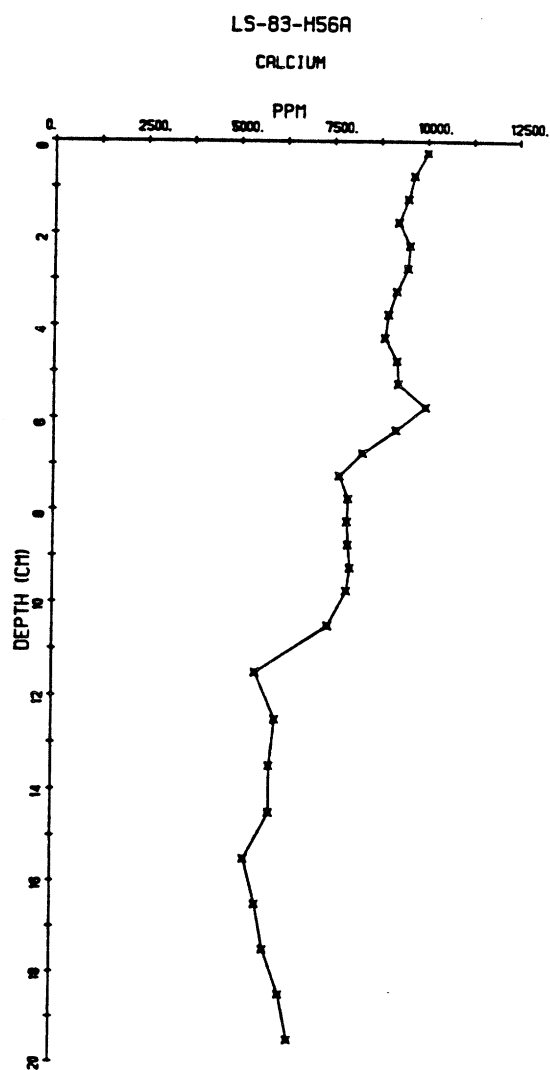
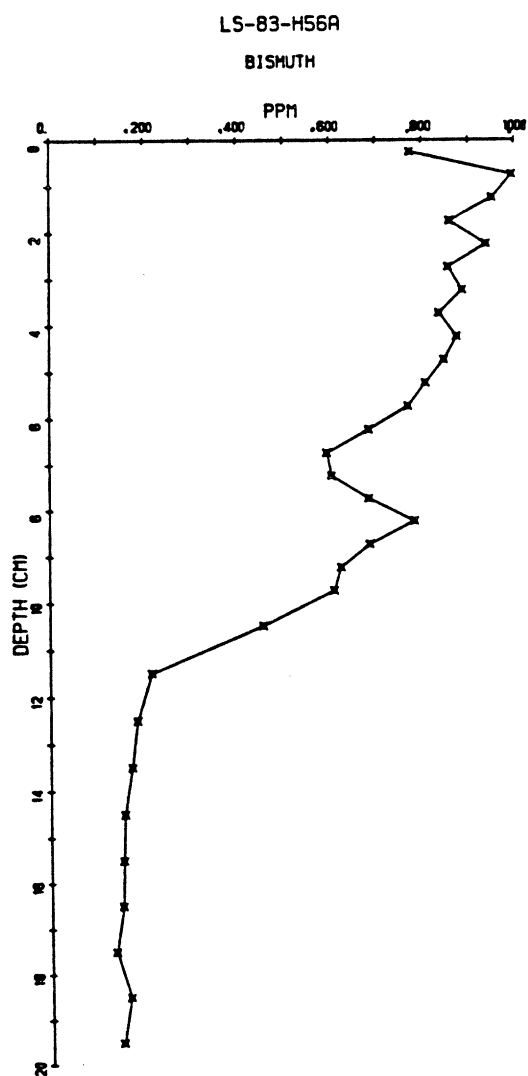


Figure 32. Vertical variation of bismuth and calcium in Lake Superior sediments at station LS-83-H56A.

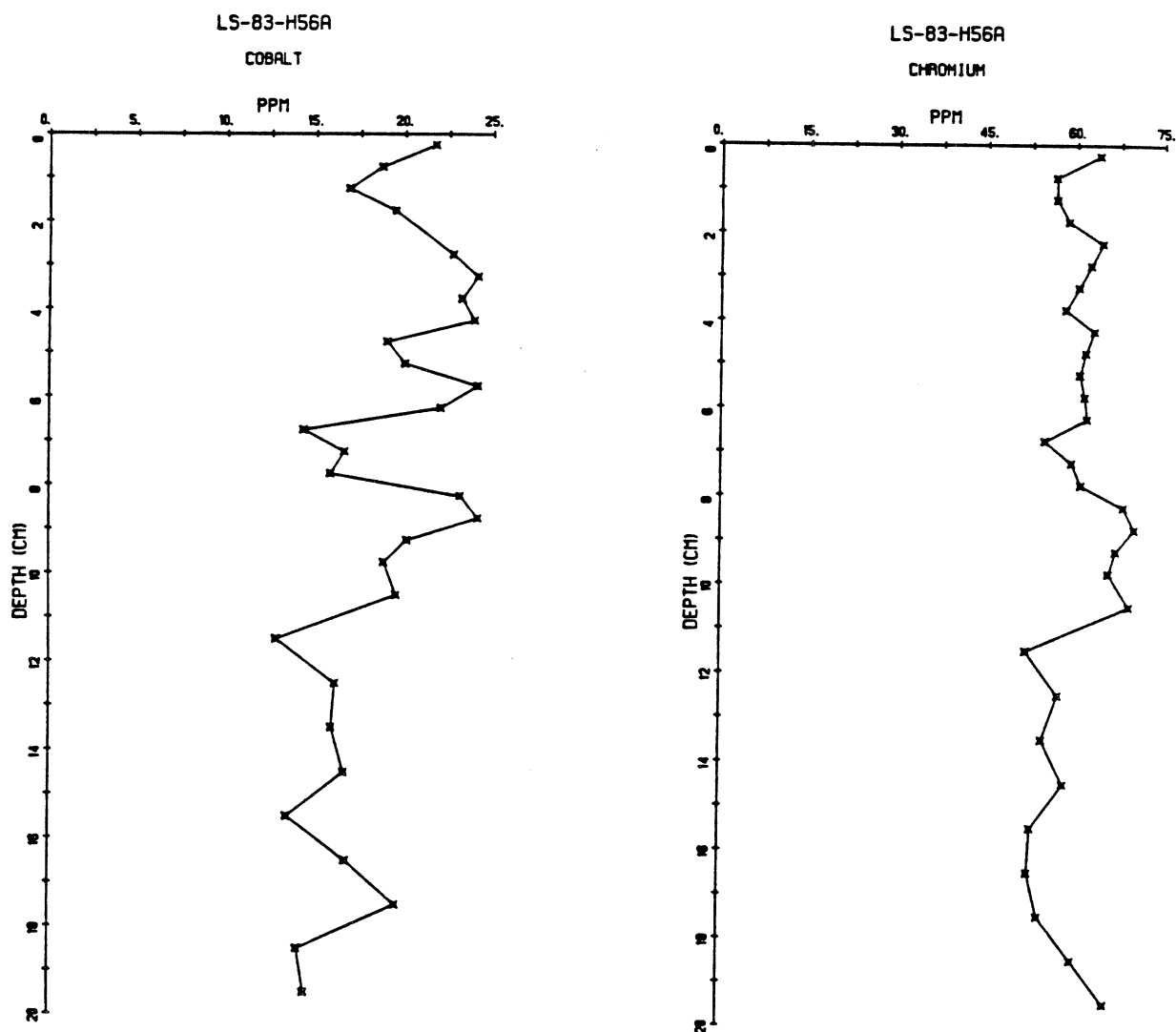


Figure 33. Vertical variation of cobalt and chromium in Lake Superior sediments at station LS-83-H56A.

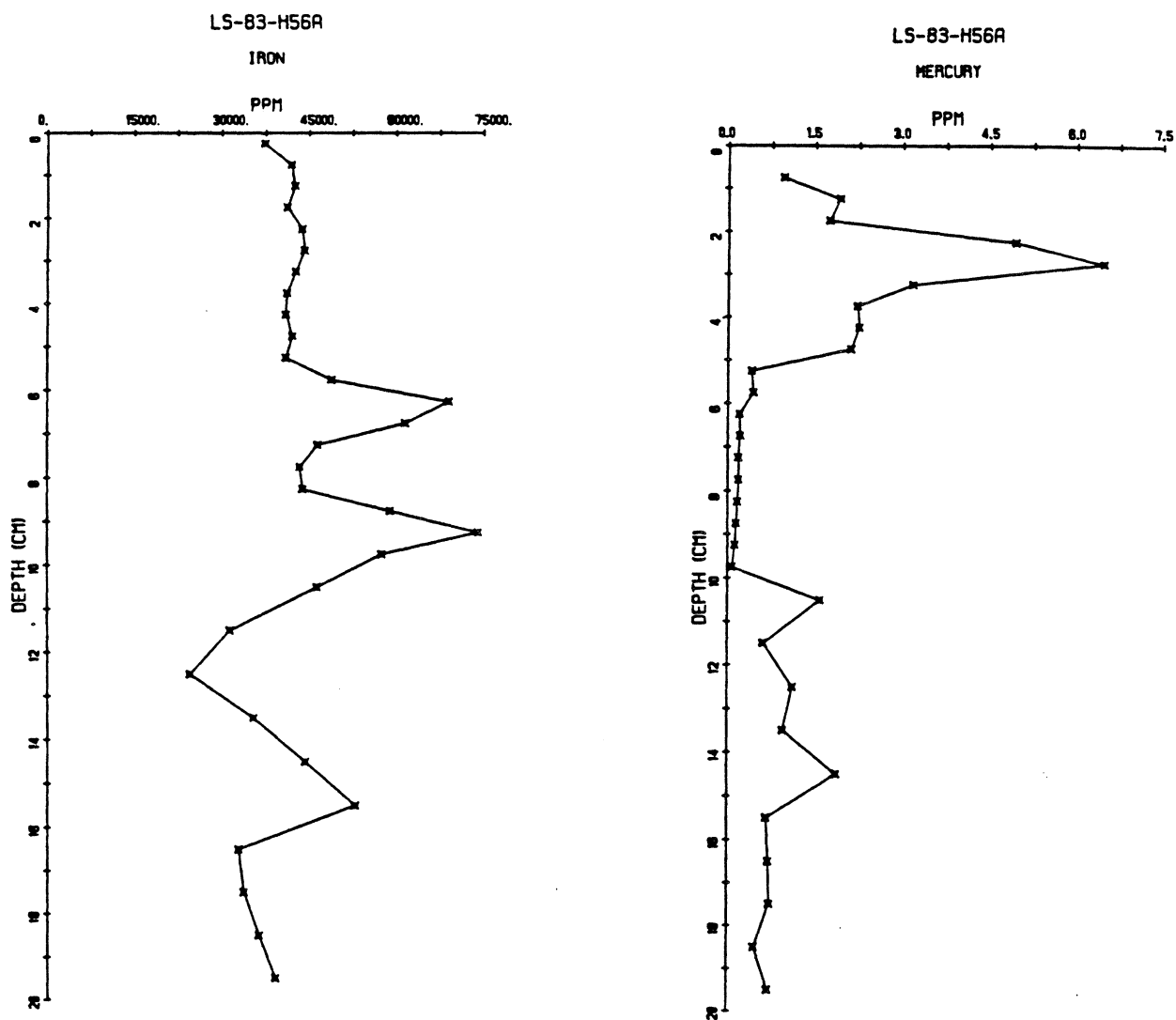


Figure 34. Vertical variation of iron and mercury in Lake Superior sediments at station LS-83-H56A.

We expect neither manganese nor magnesium to be preserved in Great Lakes sediments as deposited (Rossmann 1984b). Both can be remobilized by diagenetic process. Magnesium concentrations are quite constant within Lake Superior sediments (Fig. 35). Its high concentration at the surface may be related either to deposition of sediments enriched in magnesium or to diagenetic remobilization. Manganese concentrations within Lake Superior sediments are also quite consistent throughout the length of the core (Fig. 35). The exception is elevated concentrations at a depth of approximately 6 cm. This depth represents the depth of penetration of oxygenated waters into the sediment. The relatively high concentration of manganese at 6 cm is due to diagenetic remobilization of manganese from deeper sediments and precipitation of hydrated manganese oxides in higher pH, oxygenated sediments (Rossmann 1984b).

Nickel concentrations increase slightly in recent sediments and lead concentrations increase dramatically (Fig. 36). Nickel profiles may be impacted by diagenesis (Rossmann 1984b). Lead is not significantly impacted by diagenesis (Johansen et al. 1983, Rossmann and Robbins 1983, Rossmann 1984b). For Lake Ontario cores, lead concentrations peaked within the time period of 1940 to present with concentrations decreasing in recent years (Rossmann and Robbins 1983). The Lake Superior sedimentation rate is expected to be considerably lower than that for Lake Ontario. Thus, the resolution for the Lake Superior contaminant profiles in sediment is less than that for Lake Ontario. The Lake Superior sediments appear to have reached peak lead concentrations. Because inputs of lead to the Great Lakes are primarily atmospheric, it is expected that the concentrations will decrease with time as they have in Lake Ontario sediments.

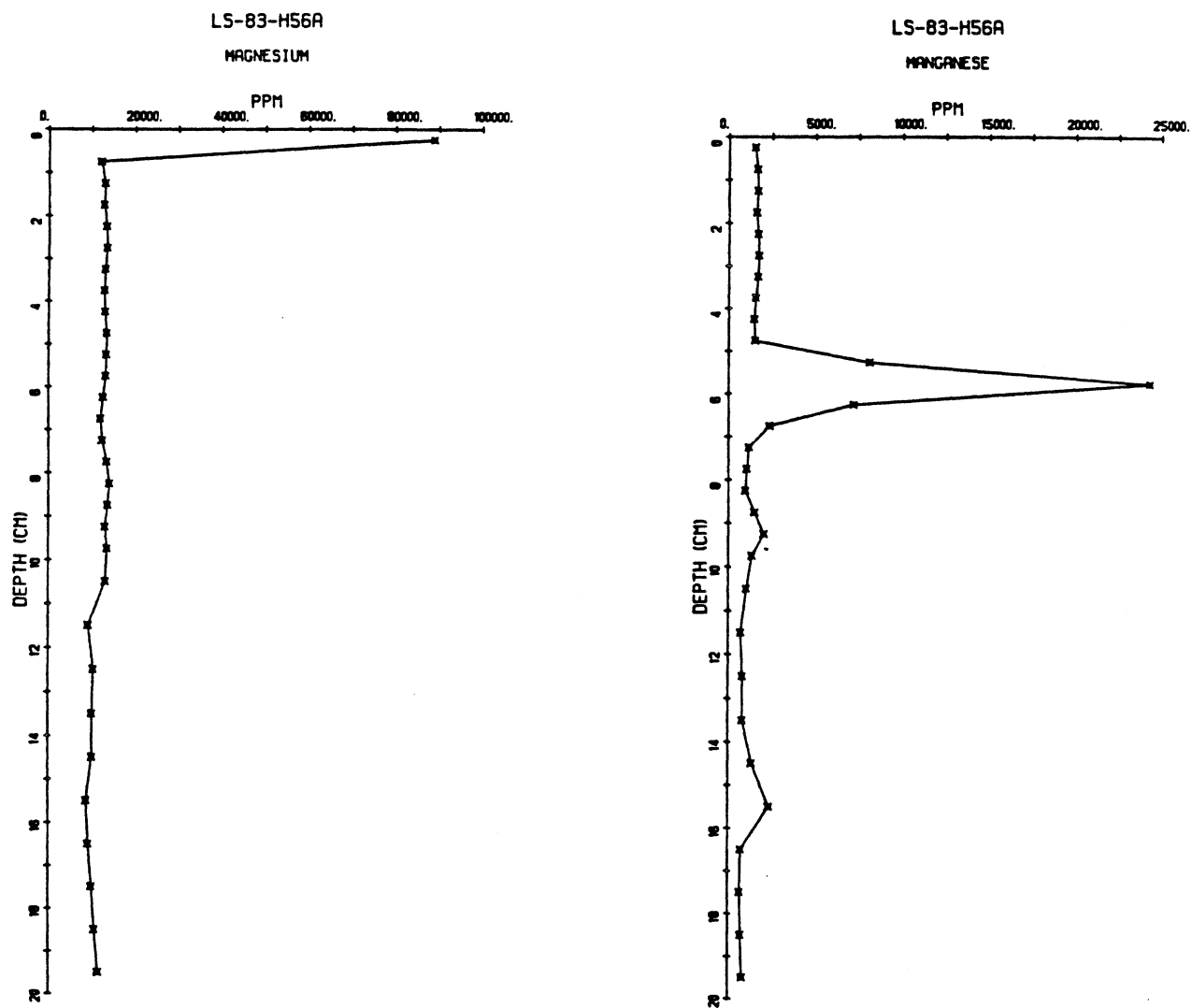


Figure 35. Vertical variation of magnesium and manganese in Lake Superior sediments at station LS-83-H56A.

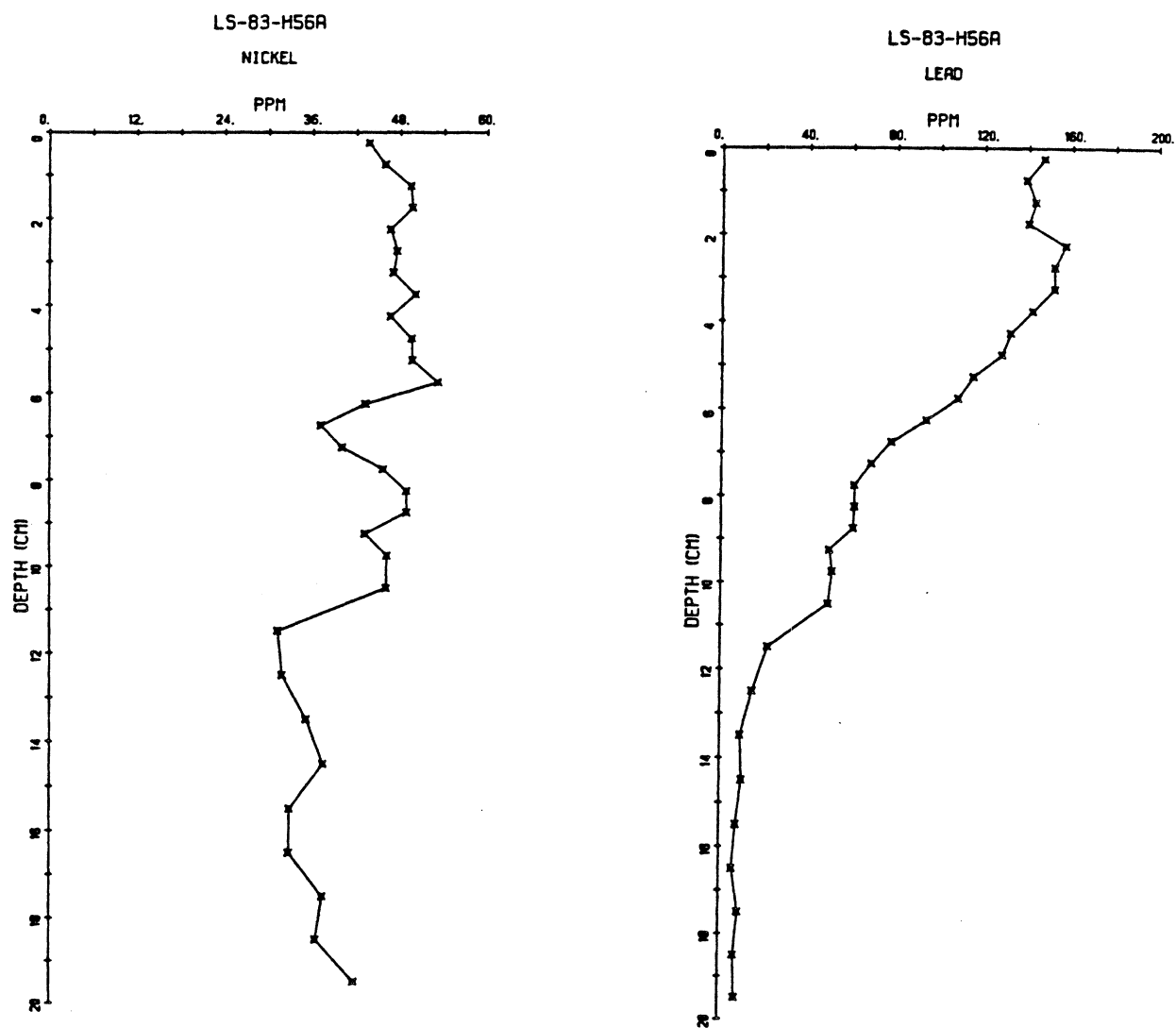


Figure 36. Vertical variation of nickel and lead in Lake Superior sediments at station LS-83-H56A.

Lake Superior concentrations of zinc in the sediment have increased with time, and concentrations of the fraction insoluble have decreased (Fig. 37). Zinc is not significantly remobilized by sediment diagenesis (Rossmann 1984b). High concentrations at the surface are hypothesized to be associated with organic matter, which degrades rapidly in the upper few centimeters of sediment. The remaining zinc is preserved. The fraction insoluble represents that fraction of the sediment insoluble in 10% v/v hydrochloric acid. Its decrease with time is hypothesized to be the result of its dilution by more soluble components, such as organic matter.

SUMMARY

Twenty stations were occupied during 1983 for the collection of water samples for trace metal analyses. Samples were analyzed for dissolved and particulate concentrations of silver, aluminum, arsenic, boron, barium, beryllium, bismuth, cadmium, cobalt, chromium, copper, iron, lithium, manganese, molybdenum, nickel, lead, antimony, selenium, tin, strontium, vanadium, and zinc and total and dissolved concentrations of mercury.

For Lake Superior water, mean total arsenic, iron, and manganese, median total iron, and median dissolved manganese and strontium showed a significant linear change with time. Excluding median dissolved strontium, concentrations of all these metals appear to be decreasing; median dissolved strontium is increasing. The general lack of trends that can be calculated is directly related to the sparsity and unacceptable quality of historical data.

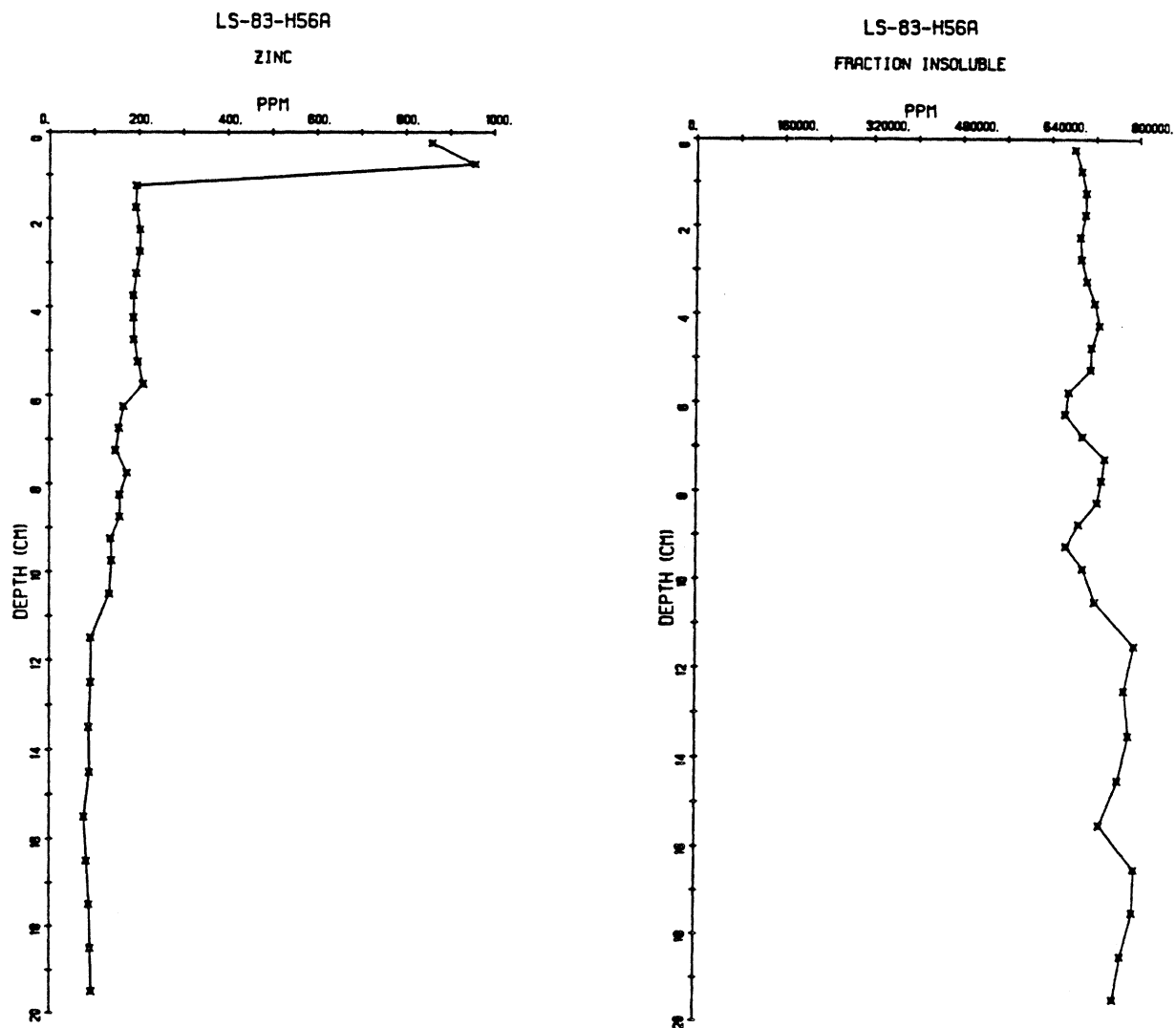


Figure 37. Vertical variation of zinc and fraction insoluble in Lake Superior sediments at station LS-83-H56A.

For the sediments of Lake Superior, concentrations of metals have changed within the last 50 years. Bismuth, calcium, cobalt, nickel, and zinc concentrations have increased. Mercury concentrations peaked between 1940 and 1970 and have been decreasing since then. Lead concentrations appear to have reached their peak and have recently become constant.

The calculated toxicity unit, an indicator of the potential toxicity of metal mixtures, was 0.49 compared to 3.91, 4.16, and 0.808 for Lakes Erie, Michigan, and Huron, respectively. The major contributors to the Lake Superior toxicity unit were cadmium, copper, and selenium.

Dissolved copper concentrations were significantly higher in eastern than those in central and western Lake Superior. Dissolved lithium concentrations were significantly higher in eastern than those in western Lake Superior. Particulate aluminum concentrations in western Lake Superior were significantly higher than those in eastern Lake Superior, and particulate selenium concentrations in the eastern region of the lake were significantly higher than those in the western region.

The vertical variation of metals was dependent upon a number of factors, including contamination of samples during collection, the possible existence of a near-bottom nephloid layer, and the erosion of the shoreline. Contamination during collection is postulated to have occurred during the storage of Niskin bottles in the cocked position, lowering of the Rossette sample to the bottom and stirring up the sediments, or inadequate flushing of the bottles prior to triggering. High epilimnetic concentrations of particulate aluminum, particulate cadmium, particulate cobalt, particulate chromium, particulate copper, dissolved iron, particulate iron, dissolved manganese, particulate manganese, particulate molybdenum, dissolved vanadium, particulate vanadium,

and particulate zinc appear to be directly related to the erosion of shoreline bluffs composed of red clay.

Total concentrations of metals which existed primarily in the particulate rather than in the dissolved phase in water were quite variable. Aluminium, cadmium, iron, mercury, manganese, and lead were primarily associated with the particulate fraction. Significant fractions of the total nickel and selenium were associated with the particulate fraction, and a minor fraction of the copper was associated with the particulate fraction.

In general, metal concentrations in the open waters of Lake Superior were less than those reported for Lakes Huron, Erie, and Michigan. For Lake Superior waters, there are no apparent metal problems associated with high metal concentrations at the present time.

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Appendix 1. Measured dissolved metal concentrations (ug/L) in Lake Superior waters collected during 1983. See Figure 1 for station locations.

Station	Depth m	Ag	Al	As	B	Ba	Be	Bi	Cd
LS-83-2	1.	-0.0016W	3.2	0.44	-12.W	20.	-0.032W	-0.034W	0.010
LS-83-12	1.	0.0003T	0.45T	0.52	-35.W	18.	-0.031W	-0.036W	0.0040T
LS-83-22	1.	-0.0027W	-0.22W	0.40	-12.W	20.	-0.013W	-0.023W	0.0060T
LS-83-25	1.	-0.0022W	0.45T	0.44	-32.W	22.	-0.047W	-0.033W	0.0050T
LS-83-42	1.	-0.0022W	-0.35W	0.44	-27.W	19.	-0.017W	-0.026W	0.0080
LS-83-45	1.	-0.0005W	0.65	0.45	-32.W	21.	-0.017W	-0.039W	0.0060T
LS-83-62	1.	-0.0019W	1.6	0.56	-22.W	22.	-0.015W	-0.031W	0.0040T
LS-83-62VP	1.	-0.0011W	0.95	0.48	-40.W	21.	-0.022W	-0.046W	0.0030T
LS-83-62VP	16.	-0.0031W	0.85	0.60	-32.W	23.	-0.017W	-0.027W	0.0030T
LS-83-62VP	30.	-0.0049W	0.85	0.51	-0.	21.	-0.021W	-0.049W	0.0020T
LS-83-62VP	72.	-0.0000W	2.4	0.84	-0.	22.	-0.017W	-0.024W	0.0080
LS-83-62VP	102.	-0.0055W	26.2	0.84	-0.	20.	-0.024W	-0.032W	0.0050T
LS-83-62VP	110.	-0.0027W	0.75	0.44	-18.W	18.	-0.030W	-0.043W	0.013
LS-83-80#1	1.	-0.0037W	1.6	0.60	-30.W	18.	-0.021W	-0.051W	0.0090
LS-83-80#2	1.	-0.0046W	-0.080W	0.48	-39.W	17.	-0.020W	-0.13W	0.0050T
LS-83-84	1.	-0.0032W	4.4	0.54	-16.W	20.	-0.037W	-0.16W	0.012
LS-83-102	1.	-0.0032W	1.4	0.90	-26.W	18.	-0.032W	-0.15W	0.0040T
LS-83-113	1.	-0.0014W	10.2	0.88	-2.1W	19.	-0.021W	-0.098W	0.0070T
LS-83-125	1.	-0.0038W	0.25T	0.61	-19.W	22.	-0.015W	-0.16W	0.0070T
LS-83-133	1.	-0.0047W	0.75	0.54	-30.W	22.	-0.046W	-0.14W	0.0090
LS-83-149	1.	-0.0032W	1.6	0.46	-28.W	23.	-0.047W	-0.16W	0.0030T
LS-83-157#1	1.	-0.0010W	1.6	0.64	-28.W	21.	-0.046W	-0.15W	0.0060T
LS-83-157#2	1.	-0.0005W	0.35T	0.67	-26.W	22.	-0.014W	-0.13W	0.0080
LS-83-169	1.	-0.0037W	1.4	0.50	25.T	20.	-0.040W	-0.14W	0.010
LS-83-182	1.	-0.0032W	6.4	0.54	-13.W	21.	-0.034W	-0.13W	0.0070T
LS-83-194	1.	0.0099	0.55T	0.43	-29.W	25.	-0.043W	-0.15W	0.0020T
LS-83-208	1.	-0.0032W	1.2	0.48	-11.W	27.	-0.032W	-0.12W	0.012
LS-83-208VP	1.	-0.0050W	2.0	0.66	13.T	25.	-0.031W	-0.13W	0.0020T
LS-83-208VP	5.	-0.0041W	1.4	0.51	-33.W	26.	-0.030W	-0.017W	0.011
LS-83-208VP	14.	-0.0041W	4.0	0.74	-15.W	24.	-0.039W	-0.15W	0.0020T
LS-83-208VP	50.	-0.0045W	2.4	0.80	-16.W	22.	-0.030W	-0.13W	-0.0024W
LS-83-208VP	100.	-0.0009W	3.6	0.72	-3.0W	22.	-0.033W	-0.15W	-0.0005W
LS-83-208VP	128.	-0.0037W	0.35T	0.79	-26.W	24.	-0.033W	-0.13W	0.0010T
LS-83-208VP	136.	-0.0042W	3.6	0.73	-33.W	19.	-0.031W	-0.17W	0.0010T
LS-83-218	1.	-0.0035W	3.0	0.52	-42.W	22.	-0.025W	-0.16W	0.0010T

W=below limit of detection.

T=below criterion of detection.

-0.=not analyzed.

Appendix 1. Continued.

Station	Depth m	Co	Cr	Cu	Fe	Hg	Li	Mn	Mo
LS-83-2	1.	0.028	0.063	1.0	1.7	0.014T	0.70	0.36	0.19
LS-83-12	1.	0.014	0.033	0.86	0.34	0.022T	0.70	0.11	0.095
LS-83-22	1.	-0.0003W	0.13	0.91	0.61	0.W	0.64	0.088	0.17
LS-83-25	1.	0.0091W	0.18	0.85	0.31	0.056	0.64	0.11	0.12
LS-83-42	1.	-0.0004W	0.023	0.77	0.82	-0.0070W	0.66	0.11	0.14
LS-83-45	1.	0.0091W	0.077	0.75	0.50	0.0080T	0.66	0.11	0.12
LS-83-62	1.	0.0044W	0.057	0.79	0.47	0.010T	0.70	0.11	0.18
LS-83-62VP	1.	0.0084W	0.048	0.77	0.54	0.010T	0.63	0.098	0.17
LS-83-62VP	16.	-0.0004W	0.054	0.70	0.087	-0.0020W	0.59	0.098	0.19
LS-83-62VP	30.	-0.0003W	0.10	0.69	0.087	-0.015W	0.57	0.046	0.15
LS-83-62VP	72.	0.0044W	0.36	0.69	0.82	0.017T	0.59	0.053	0.096
LS-83-62VP	102.	0.018	0.090	0.77	4.4	0.W	0.59	0.12	0.086
LS-83-62VP	110.	-0.0047W	0.12	0.70	1.5	0.0090T	0.58	0.053	0.086
LS-83-80#1	1.	0.0044W	0.054	0.58	0.43	0.W	0.57	0.058	0.089
LS-83-80#2	1.	0.0041W	0.043	0.71	0.66	0.0060T	0.60	0.072	0.10
LS-83-84	1.	0.011W	0.81	0.65	1.3	-0.010W	0.64	0.11	0.13
LS-83-102	1.	0.020	0.36	0.65	0.48	0.0070T	0.61	0.088	0.12
LS-83-113	1.	0.032	0.50	0.69	0.30	0.0050T	0.62	0.23	0.10
LS-83-125	1.	0.0057W	0.080	0.66	0.72	-0.0030W	0.61	0.12	0.15
LS-83-133	1.	0.0057W	0.49	0.66	0.64	-0.0060W	0.64	0.19	0.14
LS-83-149	1.	0.0008W	0.054	0.74	0.82	-0.024W	0.63	0.12	0.26
LS-83-157#1	1.	0.0010W	0.023T	0.70	0.44	-0.011W	0.62	0.088	0.17
LS-83-157#2	1.	0.0086W	0.90	0.77	1.1	-0.031W	0.60	0.098	0.18
LS-83-169	1.	0.011W	0.035	0.69	0.44	-0.025W	0.56	0.098	0.18
LS-83-182	1.	0.021	0.39	0.74	3.3	0.0090T	0.60	0.14	0.14
LS-83-194	1.	0.0055W	0.19	0.68	0.62	-0.014W	0.59	0.046	0.12
LS-83-208	1.	0.0058W	0.090	0.78	6.3	0.012T	0.60	0.32	0.11
LS-83-208VP	1.	0.022	0.052	0.69	8.7	0.042	0.68	0.35	0.12
LS-83-208VP	5.	0.0058W	3.9	0.61	8.3	0.056	0.71	0.35	0.42
LS-83-208VP	14.	-0.0042W	0.080	0.57	0.92	-0.023W	0.66	0.060	0.40
LS-83-208VP	50.	0.0074W	0.070	0.62	0.82	0.0090T	0.66	0.039	0.20
LS-83-208VP	100.	0.0020W	0.067	0.56	1.1	0.028T	0.66	0.040	0.19
LS-83-208VP	128.	0.012	0.14	0.62	5.6	0.038	0.58	0.088	0.15
LS-83-208VP	136.	0.0019W	0.22	0.59	1.6	-0.016W	0.59	0.061	0.14
LS-83-218	1.	0.011	0.40	0.61	2.3	0.0020T	0.62	0.21	0.18

W=below limit of detection.

T=below criterion of detection.

-0.=not analyzed.

Appendix 1. Continued.

Station	Depth m	Ni	Pb	Sb	Se	Sn	Sr	V	Zn
LS-83-2	1.	0.068	0.0060	0.11	0.091	-0.	55.	0.41	0.26
LS-83-12	1.	0.072	-0.017W	0.14	0.085	-0.0054W	42.	0.30	0.24
LS-83-22	1.	0.070	0.012	0.082	0.049T	-0.0005W	33.	0.28	0.22
LS-83-25	1.	0.075	-0.0040W	-0.11W	0.071	0.0006	34.	0.68	0.33
LS-83-42	1.	0.011	-0.011W	0.11	0.089	-0.0009W	42.	0.36	0.25
LS-83-45	1.	0.033	-0.0030W	0.098	0.11	0.0009W	37.	0.29	0.26
LS-83-62	1.	0.043	-0.014W	0.062	-0.040W	0.0011W	41.	0.27	0.57
LS-83-62VP	1.	0.055	-0.0070W	0.062	-0.0056W	-0.0123W	38.	0.11	0.83
LS-83-62VP	16.	0.033	-0.014W	0.091	0.11	-0.0025W	45.	0.14	0.57
LS-83-62VP	30.	-0.018W	-0.0060W	0.11	0.14	-0.	42.	0.41	0.32
LS-83-62VP	72.	-0.011W	0.014	0.082	0.074	-0.	43.	0.29	0.33
LS-83-62VP	102.	0.13	-0.016W	-0.036W	0.024T	-0.	38.	0.41	0.42
LS-83-62VP	110.	0.017	-0.016W	0.074	0.041T	-0.0008W	42.	0.27	0.30
LS-83-80#1	1.	0.022	-0.0040W	0.056	0.12	0.W	38.	0.29	0.22
LS-83-80#2	1.	0.040	0.042	0.081	0.061	0.0035W	45.	0.28	0.34
LS-83-84	1.	0.027	0.052	0.042	0.10	0.0086W	48.	0.32	1.4
LS-83-102	1.	0.025	-0.023W	0.065	0.062	-0.0021W	42.	0.31	0.31
LS-83-113	1.	0.025	-0.012W	0.055	0.0094W	0.W	51.	0.15	0.28
LS-83-125	1.	0.017	0.017	0.057	0.015W	-0.0006W	38.	0.62	0.21
LS-83-133	1.	0.022	0.062	0.19	0.14	0.0047W	64.	0.37	0.24
LS-83-149	1.	0.018	0.10	0.21	0.083	-0.0018W	44.	0.31	0.62
LS-83-157#1	1.	0.020	0.0060	0.18	0.053T	0.0012W	38.	0.31	0.20
LS-83-157#2	1.	0.018T	0.062	0.078	0.014W	0.0035W	35.	0.60	0.98
LS-83-169	1.	0.049	0.0060	0.18	0.082	0.0066W	50.	0.32	0.24
LS-83-182	1.	0.050	0.014	0.14	0.072	0.0082W	51.	0.31	0.37
LS-83-194	1.	0.032	0.020	0.13	0.023W	0.0015W	46.	0.39	0.26
LS-83-208	1.	0.088	0.W	0.18	0.052T	-0.W	44.	0.31	0.83
LS-83-208VP	1.	0.11	0.46	0.15	0.023W	-0.0027W	44.	0.36	0.86
LS-83-208VP	5.	0.088	0.0060	0.11	0.16	0.0032W	41.	0.32	0.56
LS-83-208VP	14.	0.068	-0.019W	0.14	0.081	0.0020W	45.	0.30	0.47
LS-83-208VP	50.	0.077	0.W	0.082	0.093	0.0059W	33.	0.32	0.19
LS-83-208VP	100.	-0.0062W	0.062	0.050	0.13	0.0020T	32.	0.30	0.14
LS-83-208VP	128.	0.087	0.022	0.071	0.12	0.011T	60.	0.29	0.52
LS-83-208VP	136.	0.034	0.011	0.065	0.16	0.0018W	41.	0.30	0.26
LS-83-218	1.	0.0014T	0.0050	0.072	0.13	0.0008W	52.	0.24	0.41

W=below limit of detection.

T=below criterion of detection.

-0.=not analyzed.

Appendix 2. Measured particulate metal concentrations (ug/L) in 1983 Lake Superior waters collected during 1983. See Figure 1 for station locations.

Station	Depth m	Ag	Al	As	B	Ba	Be	Bi	Cd
LS-83-2	1.	0.0011	0.20	0.016W	3.0	-0.026W	-0.0042W	0.020W	0.016
LS-83-12	1.	0.0012	0.66	0.039W	0.94T	-0.027W	-0.0048W	0.0050W	0.020
LS-83-22	1.	0.0017	2.5	0.050	4.0	0.096T	-0.0036W	-0.013W	0.021
LS-83-25	1.	0.0010	0.79	0.036W	-1.2T	-0.031W	-0.0034W	0.0035W	0.0095W
LS-83-42	1.	0.0010	1.5	0.043	3.1W	0.012T	-0.0026W	-0.012W	0.016
LS-83-45	1.	0.0008	2.5	0.017W	3.2	0.0035T	-0.0038W	0.0085W	0.031
LS-83-62	1.	0.0014	2.9	0.025W	3.9	0.16	-0.0035W	-0.0020W	0.038
LS-83-62VP	1.	0.0010	2.9	0.021W	-2.4W	0.46	-0.0037W	0.020T	0.014
LS-83-62VP	16.	0.0010	2.5	-0.0020W	12.	0.16	-0.0034W	-0.0095W	0.026
LS-83-62VP	30.	0.0011	2.4	0.0026W	-1.2T	0.19	-0.0025W	0.0035W	0.016
LS-83-62VP	72.	0.0010	3.8	-0.015W	-1.0W	0.13	-0.0021W	0.0005W	0.024
LS-83-62VP	102.	0.0013	8.7	-0.0026W	-0.088W	0.26	-0.0021W	-0.0095W	0.030
LS-83-62VP	110.	0.0011	11.	0.027W	0.93W	0.23	-0.0015W	0.025	0.027
LS-83-80#1	1.	0.0007	1.6	0.0084W	2.2	0.094T	-0.0008W	0.012W	0.024
LS-83-80#2	1.	0.0013	2.8	0.024W	2.5W	0.064T	-0.0030W	0.012W	0.024
LS-83-84	1.	0.0010	1.5	-0.0030W	24.	0.086T	-0.0030W	0.014W	0.013
LS-83-102	1.	0.0009	2.8	0.0010W	-2.9W	0.058T	-0.0014W	-0.014W	0.0085W
LS-83-113	1.	0.0014	2.6	0.022W	-1.2W	0.015T	-0.0015W	0.018W	0.028
LS-83-125	1.	0.0011	3.0	0.010T	-0.90T	0.017W	-0.0040W	0.0070T	0.0065W
LS-83-133	1.	0.0014	9.5	-0.0030W	-2.5W	0.017W	-0.0015W	0.011W	0.035
LS-83-149	1.	0.0010	5.0	-0.034W	-2.6W	0.14	-0.0002W	-0.0095W	0.024
LS-83-157#1	1.	0.0010	2.2	-0.038W	-2.2W	0.020W	-0.0026W	0.020	0.0010W
LS-83-157#2	1.	0.0012	2.1	-0.038W	-0.52W	-0.057W	-0.0026W	0.034	0.0075T
LS-83-169	1.	0.0032	3.3	0.019W	-1.5W	0.14	-0.0052W	-0.0045W	0.026
LS-83-182	1.	0.0011	5.2	-0.0024W	-1.3W	0.11	-0.0015W	-0.0055W	0.017
LS-83-194	1.	0.0015	6.0	0.0031W	-1.2W	0.025T	-0.0008W	0.0080W	0.036
LS-83-208	1.	0.0018	23.	0.039W	-4.2W	0.29	-0.0009W	-0.018W	0.024
LS-83-208VP	1.	0.0026	24.	-0.0017W	-1.4W	0.36	-0.0009W	0.021W	0.042
LS-83-208VP	5.	0.0022	24.	0.092	-4.1W	0.24	-0.0040W	-0.0030W	0.028
LS-83-208VP	14.	0.0019	5.1	0.035T	-2.0W	0.14	-0.0005W	0.019W	0.017W
LS-83-208VP	50.	0.0020	6.7	0.019W	-2.0W	0.16	-0.0030W	-0.0015W	0.016W
LS-83-208VP	100.	0.0032	10.	0.024W	-2.8W	0.075T	-0.0051W	0.010W	0.0045W
LS-83-208VP	128.	0.0016	24.	0.027W	4.5	0.20	-0.0035W	-0.010W	0.010W
LS-83-208VP	136.	0.0025	20.	0.021W	-1.3W	0.19	-0.0012W	-0.0095W	0.017W
LS-83-218	1.	0.0016	9.0	0.0040W	2.9W	0.28W	-0.0016W	-0.026W	0.026

W=below limit of detection.

T=below criterion of detection.

-0.=not analyzed.

Appendix 2. Continued.

Station	Depth m	Co	Cr	Cu	Fe	Hg(1)	Li	Mn	Mo
LS-83-2	1.	0.0005T	0.0035T	0.051	0.45	0.10	0.0021W	0.18	0.0097
LS-83-12	1.	0.0009T	0.1	0.088	1.2	0.010	0.0020W	0.16	0.0063T
LS-83-22	1.	0.0004T	0.018	1.0	3.7	0.004	0.0007W	0.18	0.013
LS-83-25	1.	-0.0009W	0.019	0.15	0.74	-0.030	-0.0058W	0.12	0.011
LS-83-42	1.	-0.0000W	0.015	0.12	2.8	0.073	-0.0004W	0.18	0.010
LS-83-45	1.	0.0013T	0.014	0.16	2.9	0.023	-0.0039W	0.033	0.0056T
LS-83-62	1.	-0.0009W	0.065T	0.12	1.6	-0.0080	0.0075T	0.24	0.0049T
LS-83-62VP	1.	0.0023T	0.086	0.066	2.8	-0.	-0.0006W	0.21	0.015
LS-83-62VP	16.	-0.0012W	0.0075T	0.13	3.6	-0.	-0.0015W	0.17	0.0094T
LS-83-62VP	30.	0.0019T	0.0050T	0.19	3.2	-0.	0.0015W	0.066	0.0031T
LS-83-62VP	72.	0.0012T	0.0065T	0.14	2.0	-0.	-0.0013W	0.22	-0.
LS-83-62VP	102.	0.0041	0.016	0.16	5.4	-0.	0.0010W	0.17	0.0050T
LS-83-62VP	110.	0.0035	0.012	0.13	6.9	-0.	0.0119	0.28	0.0055T
LS-83-80#1	1.	-0.0006W	0.0015T	0.12	1.2	-0.015	0.0067T	0.092	0.0048T
LS-83-80#2	1.	-0.0005W	0.0020T	0.22	1.1	-0.	-0.0062W	0.090	0.0052T
LS-83-84	1.	-0.0022W	0.0025T	0.049	0.96	0.019	0.0075W	0.072	0.0025T
LS-83-102	1.	-0.0011W	0.0035T	0.060	1.8	-0.020	-0.0033W	0.17	0.0040T
LS-83-113	1.	-0.0030W	0.1	0.078	1.3	-0.018	0.0086W	0.027	0.0035T
LS-83-125	1.	-0.0014W	0.0055T	0.12	1.7	0.0050	0.0077T	0.18	0.0053T
LS-83-133	1.	0.0008T	0.012	0.14	7.3	-0.014	0.0086	0.22	0.0070T
LS-83-149	1.	-0.0001W	0.012	0.17	4.5	0.0010	-0.0008W	0.20	0.0053T
LS-83-157#1	1.	0.0019T	0.0095	0.22	2.0	-0.0080	-0.0039W	0.099	0.0043T
LS-83-157#2	1.	0.0009T	0.0080	0.23	2.2	-0.	-0.0023W	0.11	0.0028T
LS-83-169	1.	0.0004T	0.020	0.12	2.1	0.035	-0.0034W	0.13	0.0092T
LS-83-182	1.	-0.0003W	0.0050T	0.071	3.8	-0.029	-0.0002W	0.16	0.012
LS-83-194	1.	0.0026	0.026	0.10	5.9	0.032	-0.0014W	0.16	0.0079T
LS-83-208	1.	0.0091	0.046	0.11	31.	0.013	0.0126	1.0	0.0057T
LS-83-208VP	1.	0.0074	0.056	0.19	29.	-0.	0.0010W	1.1	0.012
LS-83-208VP	5.	0.0090	0.086	0.13	29.	-0.	0.0048T	1.1	0.020
LS-83-208VP	14.	0.0024T	0.022	0.11	6.4	-0.	-0.0024W	0.28	0.0009T
LS-83-208VP	50.	0.0003T	0.014	0.099	6.2	-0.	-0.0035W	0.33	0.0080T
LS-83-208VP	100.	0.0022T	0.014	0.072	6.6	-0.	-0.0014W	0.34	0.0019T
LS-83-208VP	128.	0.0046	0.034	0.093	17.	-0.	0.0072T	0.69	0.0034T
LS-83-208VP	136.	0.0069	0.086	0.11	23.	-0.	0.0095W	0.92	0.0082T
LS-83-218	1.	0.0007T	0.0045T	0.066	7.4	-0.023	-0.0020W	0.28	0.015

W=below limit of detection.

T=below criterion of detection.

-0.=not analyzed.

(1) Particulate mercury concentration calculated from total and dissolved concentrations; no T's or W's inferred.

Appendix 2. Continued.

Station	Depth m	Ni	Pb	Sb	Se	Sn	Sr	V	Zn
LS-83-2	1.	0.022	0.011	-0.011W	0.13	-0.64W	-0.012W	0.0010T	0.027
LS-83-12	1.	0.0055	0.012	-0.0043W	0.083	-0.75W	-0.057W	0.018	0.18
LS-83-22	1.	0.032	0.044	-0.014W	0.086	-0.70W	-0.030W	0.0080T	0.62
LS-83-25	1.	0.024	0.022	-0.011W	0.059T	-0.78W	-0.025W	0.0070T	0.027
LS-83-42	1.	0.052	0.019	-0.016W	-0.026W	-0.86W	-0.045W	0.0005T	0.062
LS-83-45	1.	0.010	0.028	-0.012W	0.044T	-0.70W	0.015T	0.010	0.13
LS-83-62	1.	0.015	0.023	-0.0068W	0.050T	-0.74W	0.0071T	0.020	0.21
LS-83-62VP	1.	0.038	0.63	-0.016W	-0.034W	-0.66W	-0.029W	0.018	0.047
LS-83-62VP	16.	0.018	0.022	-0.0045W	0.032T	-0.75W	0.0083T	0.016	0.037
LS-83-62VP	30.	0.023	0.018	-0.012W	0.011T	-0.77W	-0.0092W	0.0090	0.11
LS-83-62VP	72.	0.012	0.057	-0.0082W	-0.0041W	-0.78W	-0.041W	0.012	0.057
LS-83-62VP	102.	0.011	0.045	-0.021W	-0.0098W	-0.66W	-0.035W	0.015	0.052
LS-83-62VP	110.	0.016	0.031	-0.030W	0.070T	-0.70W	0.095	0.016	0.072
LS-83-80#1	1.	-0.0040W	0.022	-0.012W	0.12	-0.70W	0.049T	0.012	0.067
LS-83-80#2	1.	0.010	0.035	-0.0093W	0.052T	-0.69W	0.030T	0.0050T	0.067
LS-83-84	1.	0.0065	0.011	-0.0094W	0.049T	-0.040W	-0.029W	0.0020T	0.027
LS-83-102	1.	0.038	0.016	-0.010W	0.087	-0.80W	-0.018W	0.0040T	0.027
LS-83-113	1.	-0.0075W	0.018	-0.013W	0.10	-0.72W	-0.045W	0.0005T	0.032
LS-83-125	1.	0.0040T	0.025	-0.0069W	0.0094T	-0.28W	-0.028W	0.0040T	0.097
LS-83-133	1.	0.0075	0.024	-0.028W	-0.0074W	-0.82W	-0.012W	0.016	0.15
LS-83-149	1.	0.012	0.027	-0.021W	0.018T	-0.90W	-0.028W	0.010	0.14
LS-83-157#1	1.	0.022	0.029	-0.012W	0.073	-0.84W	0.026T	0.0090	0.14
LS-83-157#2	1.	0.062	0.021	-0.012W	0.072	-0.91W	-0.045W	0.0050T	0.14
LS-83-169	1.	0.012	0.027	-0.015W	0.047T	-0.83W	-0.041W	0.016	0.14
LS-83-182	1.	0.014	0.015	-0.016W	0.028T	-0.96W	-0.021W	0.0080T	0.082
LS-83-194	1.	0.014	0.044	-0.014W	0.039T	-0.85W	0.0011T	0.017	0.057
LS-83-208	1.	0.025	0.048	-0.044W	-0.022W	-0.72W	0.055	0.064	0.12
LS-83-208VP	1.	0.042	1.9	-0.042W	-0.044W	-0.71W	0.0015T	0.070	0.36
LS-83-208VP	5.	0.12	0.044	-0.040W	-0.038W	-0.70W	0.038T	0.074	0.18
LS-83-208VP	14.	0.017	0.031	-0.017W	0.026T	-0.94W	-0.024W	0.020	0.21
LS-83-208VP	50.	0.0055	0.021	-0.018W	0.017T	-0.81W	-0.036W	0.016	0.14
LS-83-208VP	100.	0.0090	0.026	-0.020W	0.0069T	-0.80W	-0.025W	0.020	0.052
LS-83-208VP	128.	0.022	0.050	-0.020W	-0.034W	-0.75W	-0.012W	0.024	0.072
LS-83-208VP	136.	0.042	0.040	-0.026W	-0.0084W	-0.66W	0.019T	0.028	0.19
LS-83-218	1.	0.020	0.023	-0.014W	0.018T	-0.74W	-0.022W	0.010	0.14

W=below limit of detection.

T=below criterion of detection.

-0.=not analyzed.

Appendix 3. Calculated total metal concentrations (ug/L) in 1983 Lake Superior waters collected during 1983. See Figure 1 for station locations.(1)

Station	Depth m	Ag	Al	As	B	Ba	Be	Bi	Cd
LS-83-2	1.	-0.0005	3.4	0.46	-9.1	20.	-0.036	-0.014	0.026
LS-83-12	1.	0.0015	1.1	0.56	-34.	18.	-0.036	-0.031	0.024
LS-83-22	1.	-0.0009	2.3	0.44	-8.5	20.	-0.017	-0.036	0.027
LS-83-25	1.	-0.0012	1.2	0.48	-33.	22.	-0.050	-0.030	0.014
LS-83-42	1.	-0.0011	1.2	0.48	-24.	19.	-0.020	-0.038	0.024
LS-83-45	1.	0.0004	3.2	0.47	-29.	21.	-0.021	-0.030	0.037
LS-83-62	1.	-0.0005	4.5	0.58	-18.	22.	-0.018	-0.033	0.042
LS-83-62VP	1.	-0.0001	3.9	0.50	-42.	21.	-0.026	-0.026	0.016
LS-83-62VP	16.	-0.0021	3.4	0.60	-20.	23.	-0.020	-0.036	0.028
LS-83-62VP	30.	-0.0038	3.3	0.51	-0.	21.	-0.024	-0.046	0.018
LS-83-62VP	72.	0.0010	6.1	0.83	-0.	22.	-0.019	-0.024	0.032
LS-83-62VP	102.	-0.0042	35.	0.84	-0.	20.	-0.026	-0.042	0.035
LS-83-62VP	110.	-0.0016	12.	0.47	-17.	18.	-0.032	-0.018	0.040
LS-83-80#1	1.	-0.0030	3.3	0.61	-28.	18.	-0.022	-0.038	0.032
LS-83-80#2	1.	-0.0033	2.7	0.51	-36.	17.	-0.023	-0.12	0.030
LS-83-84	1.	-0.0022	6.0	0.53	8.6	20.	-0.040	-0.15	0.025
LS-83-102	1.	-0.0022	4.3	0.90	-29.	18.	-0.033	-0.16	0.012
LS-83-113	1.	0.0000	13.	0.90	-3.3	19.	-0.022	-0.080	0.035
LS-83-125	1.	-0.0027	3.2	0.62	-20.	22.	-0.019	-0.15	0.014
LS-83-133	1.	-0.0033	10.	0.53	-32.	22.	-0.048	-0.13	0.044
LS-83-149	1.	-0.0022	6.7	0.43	-31.	23.	-0.047	-0.17	0.028
LS-83-157#1	1.	0.0001	3.8	0.61	-30.	21.	-0.049	-0.13	0.0070
LS-83-157#2	1.	0.0007	2.4	0.63	-26.	22.	-0.017	-0.096	0.016
LS-83-169	1.	-0.0005	4.7	0.52	24.	20.	-0.045	-0.14	0.036
LS-83-182	1.	-0.0021	12.	0.54	-15.	21.	-0.036	-0.14	0.024
LS-83-194	1.	0.011	6.5	0.43	-30.	25.	-0.044	-0.14	0.038
LS-83-208	1.	-0.0014	24.	0.52	-15.	27.	-0.033	-0.14	0.036
LS-83-208VP	1.	-0.0023	26.	0.66	11.	25.	-0.032	-0.11	0.044
LS-83-208VP	5.	-0.0019	26.	0.60	-37.	26.	-0.034	-0.020	0.038
LS-83-208VP	14.	-0.0022	9.0	0.77	-17.	24.	-0.040	-0.13	0.019
LS-83-208VP	50.	-0.0025	9.0	0.82	-17.	22.	-0.033	-0.13	0.013
LS-83-208VP	100.	0.0023	14.	0.74	-5.7	22.	-0.038	-0.14	0.0040
LS-83-208VP	128.	-0.0021	24.	0.82	-22.	24.	-0.036	-0.14	0.012
LS-83-208VP	136.	-0.0017	23.	0.75	-34.	19.	-0.032	-0.18	0.018
LS-83-218	1.	-0.0019	12.	0.53	-39.	22.	-0.027	-0.19	0.028

-0.=not analyzed.

(1) No T's or W's inferred for calculated metal concentrations.

Appendix 3. Continued.(1)

Station	Depth m	Co	Cr	Cu	Fe	Hg(2)	Li	Mn	Mo
LS-83-2	1.	0.029	0.067	1.1	2.2	0.36	0.70	0.54	0.20
LS-83-12	1.	0.015	0.033	0.95	1.5	0.11	0.70	0.27	0.10
LS-83-22	1.	0.0001	0.15	2.0	4.3	0.088	0.64	0.27	0.18
LS-83-25	1.	0.0082	0.20	1.0	1.0	0.11	0.63	0.23	0.13
LS-83-42	1.	-0.0004	0.038	0.90	3.6	0.11	0.66	0.29	0.15
LS-83-45	1.	0.010	0.091	0.92	3.4	0.11	0.66	0.14	0.12
LS-83-62	1.	0.0035	0.064	0.92	2.1	0.11	0.71	0.35	0.18
LS-83-62VP	1.	0.011	0.13	0.84	3.3	0.098	0.63	0.30	0.18
LS-83-62VP	16.	-0.0016	0.062	0.83	3.7	0.098	0.59	0.27	0.20
LS-83-62VP	30.	0.0017	0.10	0.88	3.2	0.046	0.57	0.11	0.15
LS-83-62VP	72.	0.0057	0.37	0.83	2.8	0.053	0.59	0.28	-0.
LS-83-62VP	102.	0.022	0.11	0.93	9.9	0.12	0.59	0.29	0.091
LS-83-62VP	110.	-0.0012	0.13	0.83	8.4	0.053	0.59	0.33	0.092
LS-83-80#1	1.	0.0038	0.056	0.70	1.7	0.058	0.58	0.15	0.094
LS-83-80#2	1.	0.0036	0.045	0.94	1.7	0.072	0.59	0.16	0.10
LS-83-84	1.	0.0088	0.81	0.70	2.3	0.11	0.65	0.18	0.13
LS-83-102	1.	0.018	0.36	0.71	2.2	0.088	0.61	0.26	0.12
LS-83-113	1.	0.029	0.50	0.77	1.6	0.23	0.63	0.25	0.10
LS-83-125	1.	0.0043	0.086	0.78	2.4	0.12	0.62	0.30	0.16
LS-83-133	1.	0.0055	0.51	0.80	7.9	0.19	0.65	0.41	0.15
LS-83-149	1.	0.0007	0.066	0.91	5.3	0.12	0.63	0.32	0.26
LS-83-157#1	1.	0.0030	0.012	0.92	2.5	0.088	0.62	0.19	0.17
LS-83-157#2	1.	0.0095	0.91	1.0	3.3	0.098	0.60	0.21	0.18
LS-83-169	1.	0.012	0.056	0.82	2.5	0.098	0.56	0.22	0.19
LS-83-182	1.	0.020	0.40	0.82	7.1	0.14	0.60	0.29	0.15
LS-83-194	1.	0.0082	0.22	0.79	6.5	0.046	0.59	0.21	0.13
LS-83-208	1.	0.015	0.14	0.89	37.	0.32	0.61	1.3	0.12
LS-83-208VP	1.	0.030	0.11	0.88	38.	0.35	0.68	1.4	0.13
LS-83-208VP	5.	0.015	4.0	0.74	37.	0.35	0.71	1.5	0.44
LS-83-208VP	14.	-0.0017	0.10	0.68	7.3	0.060	0.66	0.34	0.40
LS-83-208VP	50.	0.0077	0.084	0.72	7.0	0.039T	0.66	0.37	0.21
LS-83-208VP	100.	0.0042	0.081	0.64	7.8	0.040T	0.66	0.38	0.19
LS-83-208VP	128.	0.016	0.17	0.72	22.	0.088	0.59	0.78	0.15
LS-83-208VP	136.	0.0088	0.31	0.71	25.	0.061	0.60	0.98	0.15
LS-83-218	1.	0.012	0.40	0.68	9.7	0.21	0.62	0.49	0.20

-0.=not analyzed.

(1) No T's or W's inferred for calculated metal concentrations.

(2) Measured total mercury concentration.

Appendix 3. Continued.(1)

Station	Depth m	Ni	Pb	Sb	Se	Sn	Sr	V	Zn
LS-83-2	1.	0.090	0.017	0.099	0.22	-0.	55.	0.41	0.29
LS-83-12	1.	0.078	-0.0053	0.14	0.17	-0.76	42.	0.32	0.42
LS-83-22	1.	0.10	0.056	0.068	0.14	-0.70	33.	0.29	0.84
LS-83-25	1.	0.099	0.018	-0.12	0.13	-0.78	34.	0.69	0.36
LS-83-42	1.	0.064	0.0077	0.094	0.063	-0.86	42.	0.36	0.31
LS-83-45	1.	0.043	0.025	0.086	0.15	-0.70	37.	0.30	0.39
LS-83-62	1.	0.058	0.0087	0.055	0.0096	-0.74	41.	0.29	0.78
LS-83-62VP	1.	0.092	0.62	0.046	-0.040	-0.68	38.	0.13	0.88
LS-83-62VP	16.	0.051	0.0077	0.086	0.14	-0.75	45.	0.16	0.61
LS-83-62VP	30.	0.0045	0.012	0.098	0.15	-0.	42.	0.42	0.43
LS-83-62VP	72.	0.0006	0.071	0.074	0.070	-0.	43.	0.30	0.39
LS-83-62VP	102.	0.14	0.029	-0.058	0.014	-0.	38.	0.42	0.47
LS-83-62VP	110.	0.032	0.015	0.044	0.11	-0.70	42.	0.29	0.37
LS-83-80#1	1.	0.018	0.018	0.044	0.24	-0.70	38.	0.30	0.29
LS-83-80#2	1.	0.051	0.077	0.072	0.11	-0.69	45.	0.28	0.41
LS-83-84	1.	0.033	0.063	0.033	0.15	-0.031	48.	0.32	1.4
LS-83-102	1.	0.062	-0.0068	0.055	0.15	-0.80	42.	0.32	0.34
LS-83-113	1.	0.24	0.042	0.042	0.11	-0.72	50.	0.15	0.31
LS-83-125	1.	0.021	0.042	0.050	0.24	-0.28	38.	0.62	0.31
LS-83-133	1.	0.029	0.086	0.16	0.13	-0.82	64.	0.39	0.39
LS-83-149	1.	0.030	0.13	0.19	0.10	-0.90	44.	0.32	0.76
LS-83-157#1	1.	0.041	0.035	0.17	0.12	-0.84	38.	0.32	0.34
LS-83-157#2	1.	0.080	0.083	0.066	0.086	-0.91	35.	0.60	1.1
LS-83-169	1.	0.062	0.033	0.16	0.13	-0.82	49.	0.34	0.38
LS-83-182	1.	0.064	0.029	0.12	0.10	-0.95	50.	0.32	0.45
LS-83-194	1.	0.046	0.064	0.12	0.062	-0.85	46.	0.41	0.32
LS-83-208	1.	0.11	0.048	0.14	0.030	-0.	44.	0.38	0.95
LS-83-208VP	1.	0.15	2.4	0.11	-0.022	-0.71	44.	0.43	1.2
LS-83-208VP	5.	0.20	0.050	0.070	0.12	-0.70	41.	0.40	0.74
LS-83-208VP	14.	0.085	0.012	0.12	0.11	-0.93	45.	0.32	0.68
LS-83-208VP	50.	0.083	0.021	0.064	0.11	-0.80	33.	0.34	0.33
LS-83-208VP	100.	0.0028	0.088	0.030	0.14	-0.80	32.	0.32	0.19
LS-83-208VP	128.	0.11	0.072	0.051	0.085	-0.74	60.	0.31	0.59
LS-83-208VP	136.	0.077	0.051	0.040	0.15	-0.65	41.	0.33	0.45
LS-83-218	1.	0.022	0.028	0.058	0.14	-0.74	52.	0.25	0.55

-0.=not analyzed.

(1) No T's or W's inferred for calculated metal concentrations.